330.9 J79i
Jones, Wellington Downing 010101 000
An introduction to economic ge
0 2074 0166872 9
DAVIDSON COLLEGE LIBRARY

Library of
Davidson College

Library of
Davidson College

AN INTRODUCTION TO ECONOMIC GEOGRAPHY

VOLUME I

NATURAL ENVIRONMENT AS RELATED TO ECONOMIC LIFE

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

—

THE BAKER & TAYLOR COMPANY
NEW YORK

THE CAMBRIDGE UNIVERSITY PRESS
LONDON

THE MARUZEN-KABUSHIKI-KAISHA
TOKYO, OSAKA, KYOTO, FUKUOKA, SENDAI

THE MISSION BOOK COMPANY
SHANGHAI

AN INTRODUCTION TO ECONOMIC GEOGRAPHY

VOLUME I

NATURAL ENVIRONMENT AS RELATED TO ECONOMIC LIFE

BY

WELLINGTON D. JONES

AND

DERWENT S. WHITTLESEY

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

Copyright 1925 By
The University of Chicago

All Rights Reserved

Published May 1925

330.9
J79e
v.1

Composed and Printed By
The University of Chicago Press
Chicago, Illinois, U.S.A.

ACKNOWLEDGMENT

The authors have been able to make specific acknowledgment of their indebtedness only in the cases of illustrations and quotations. Their obligations extend far beyond these—in general to the host of observers and students of the earth as the home of mankind, whose scattered contributions have been insensibly built into this book; more particularly to several scientific bureaus of the United States government, particularly the Department of Agriculture, including the Forest Service and the Weather Bureau, the Geological Survey, the Reclamation Service, the Bureau of Foreign and Domestic Commerce, and the Smithsonian Institution, and to Dr. Isaiah Bowman of the American Geographical Society, evidences of whose cordial co-operation appear throughout the work in illustrations and quotations; specifically to Professor J. Paul Goode for permission to use his homolosine map projection of the world; and in detail to the authors of previous textbooks in the field of economic geography, of which one, Salisbury, Barrows, and Tower, *Elements of Geography* (New York: Henry Holt and Co., 1912), has been, during the thirteen years since its publication, the foundation stone upon which the elementary course in college geography covered by Volume I has been built. In a different but more intimate way, publication has been facilitated by geographers who have criticized parts or all of the galley proof, by the intelligent aid of the staff of the University of Chicago Press, by the vision of the editor of the series of which this book forms a part, and particularly by Professor H. H. Barrows, whose deep sympathy and thoughtful foresight made it possible to undertake the project and in numerous ways accelerated its completion.

TABLE OF CONTENTS

Suggestions to Students and Teachers xxvii

PART I. EXERCISES

CHAPTER PAGE

I. The Scope of Economic Geography 3

II. Climate and Natural Vegetation 6

Rainy Low Latitude Type of Climate 6
Low Latitude Desert Type of Climate 8
Wet-and-dry Low Latitude and Semi-arid Low Latitude Types of Climate 9
Climates of Higher Altitudes in the Low Latitudes 11
Review of Low Latitude Types of Climate 13
Middle Latitude Climates 15
Climate of West Margins of Continents in Lower Middle Latitudes, or Dry Subtropical Climate 16
Climate of East Margins of Continents in Lower Middle Latitudes, or Humid Subtropical Type of Climate 18
Climate of West Margins of Continents in Higher Middle Latitudes, or Mild-Winter–Mild-Summer Climate 20
Humid Continental Climates with Long Summers and with Short Summers 21
Climate of East Margins of Continents in Higher Middle Latitudes, or Modified Humid Continental Type 23
Middle Latitude Desert Climate 24
Semi-arid Middle Latitude Climate 25
The Variable Weather of the Middle Latitudes—First Exercise 27
The Variable Weather of the Middle Latitudes—Second Exercise 31
The Variable Weather of the Middle Latitudes—Third Exercise 33
Climates of Higher Altitudes in the Middle Latitudes . . . 36
Review of Middle Latitude Types of Climates 37
High Latitude Climates 38

III. Land Forms and Soils 40

Comparisons between Land Forms, Soils, and Climate . . . 40
Major Land Forms 41
Mountains 41

CHAPTER PAGE

Plains 46
Hill Country 49
Plateaus 51
Minor Land Forms 54
Flooded Alluvial Plains—Valley Floodplains and Delta Plains . 55
Well-drained Alluvial Plains 59
Piedmont Alluvial Plains 60
Coastal Plains of Unconsolidated Marine Sediments 62
Ice-Scoured Plains and Hill Country and Moraine Plains . . 64
Plains of Glacial Outwash. 67
Lacustrine Plains 69
Plains Having Residual Soils 71
Soils 73
Earthquakes and Volcanic Eruptions 74
Review of Minor Land Forms 75

IV. Bedrock and Mineral Deposits 76
Bedrock as an Element of the Natural Environment 76
Mineral Deposits 77

V. Ground and Surface Waters of the Lands 79
Ground Water and Its Uses 79
Streams and Lakes as Sources of City Water Supply . . . 81
Streams for Irrigation 82
Streams for Water Power 86
Rivers as Commercial Highways 88
Great Lakes and Inland Seas as Highways 92

VI. Oceans and Their Coasts 93
The Oceans 93
Coast Lines and Harbors 96

VII. Shape, Size, and Location as Elements of the Natural Environment 98

PART II. TEXTUAL MATERIALS

Classification of Climates 103
The Rainy Low Latitude Type of Climate 105
Sensible Temperature 107
A Day in the Rainy Low Latitude Type of Climate 108
The Low Latitude Desert Type of Climate 109
Windstorms in a Low Latitude Desert 111
The Coastal Desert of Northern Chile 113
The Wet-and-Dry Low Latitude Type of Climate 114
The Semi-arid Low Latitude Type of Climate 115

PAGE

Agricultural Practices in India 116
Weather Conditions in the Zambezi Basin 118
Tropical Cyclones, Typhoons, and Hurricanes 121
High Altitude Climates in the Low Latitudes 125
Temperature Contrasts between Calcutta and Darjeeling, India 131
Climate and Civilization in the Low Latitude Climates . . . 132
The Climate of West Margins of Continents in Lower Middle Latitudes, or the Dry Subtropical Type of Climate . . . 132
Saving the Crops from Injury by Frost 135
Weather Bureau Fruit-Frost Service in Southern California. 139
Annoying Winds of the Dry Subtropical Climate 141
The Climate of East Margins of Continents in Lower Middle Latitudes, or the Humid Subtropical Type of Climate 142
Average Temperatures for Atlanta, Georgia; Los Angeles, California; Geneva, Switzerland 145
The Climate of West Margins of Continents in Higher Middle Latitudes, or the Mild-Winter–Mild-Summer Type of Climate 145
Introduction to the Continental Types of Climate 147
The Humid Continental Type of Climate with Long Summers . 147
The Humid Continental Type of Climate with Short Summers . 150
A Middle West Blizzard 151
Winter Operation of Railroads in the Northern Part of the Lower Peninsula of Michigan 152
Types of Thunderstorms 154
Tornadoes 155
Comparative Average Climatic Data for Winnipeg, Manitoba; Omaha, Nebraska; Columbus, Ohio; Portland, Maine . . . 59
The Climate of East Margins of Continents in Higher Middle Latitudes, or the Modified Humid Continental Type of Climate 159
The Continental and the Marine Influence in Climate . . 161
Climatic Data for Portland, Maine, and Portland, Oregon . 162
The Middle Latitude Desert Type of Climate 162
The Semi-arid Middle Latitude Type of Climate 163
Dry-Farming in Semi-arid Regions 164
Life of the Nomadic Khirghiz 166
Arable Land of the Earth 168
The Significance of Variable Weather in the Middle Latitude Types of Climate 168
Hourly Wind Record at University of Chicago Observatory, April 23–26, 1921 169

PAGE

Some Consequences of Weather 170
The Hot, Dry Summer of 1916 in Kansas 171
The Florida Freeze of 1894 172
The United States Weather Bureau 173
High Altitude Climates in the Middle Latitudes 180
The Agriculture of Mountain Valleys 182
The Lower High Latitude Type of Climate 183
The Subpolar or Tundra Type of Climate 184
The Polar or Ice-Cap Type of Climate 185
Cities with a Population of One Million or More 189
Comparative Climatic Data for Selected Stations 190
The Pastoral Life of the Mountain 192
Alpine Scenery. 196
The Origin of Mountains 197
Functions of Mountain Passes 198
Land Routes of Trade and Travel 202
Contrasts between Hill Country and Plain, Exemplified by the Eastern Kentucky "Mountains" and the Bluegrass . 204
Contrasts among the Major Land Forms 208
Floods in the Lower Mississippi Valley 211
Delta Cities 215
Piedmont Plain Agriculture in Southern California . . . 218
Land in the United States Unfit for Cultivation without Drainage, 1920 221
Reclamation of Tidal Marshes 222
Reclamation of Wet Land in the Netherlands 226
Coastal Dunes 228
Origin and Characteristics of Coastal Plains of Unconsolidated Marine Sediments 231
The Utilization of Ice-Scoured Plains and Hill Country . . 231
Surface Features of North America and Europe as Related to Former Continental Ice Sheets 234
Drainage of Wet Moraine Land 236
Terrace Towns of the Upper Mississippi 237
The Agents and Processes Involved in Weathering . . . 239
Soil Conditions Favorable for the Growth of Agricultural Plants 239
Types of Soils 242
The Destructiveness of Earthquakes 251
The Destructiveness of Volcanoes. 254
Engineering Problems as Related to the Depth of Bedrock 261
Building Stone. 262
Mineral Building Materials Other than Stone 263

PAGE

Minerals and Population Movements 263
Economic Aspects of Minerals 267
The Conservation of Mineral Resources 270
Virginia City, A Mining Camp 271
Chief Steel-Producing Countries, 1923 275
Chief Copper-Producing Countries, 1923 275
Unmined Coal Reserves of the World 275
Chief Coal-Producing Countries, 1923 276
Chief Petroleum-Producing Countries, 1923 276
The Artesian Water Supply of Eastern South Dakota . . . 277
Springs 278
Types of Ground-Water Occurrence 280
Surface Waters as Sources of City Water Supply 284
The Extension of Irrigation in the Nile Valley 289
Irrigation in the Utah Oasis 290
Total Land Area, Improved Land in Farms, and Irrigated Land, for Each of the States of the United States 292
Irrigated and Irrigable Land in the United States, 1919 and 1920, in Acres 294
The Salt River Valley Irrigation Project 295
The Practice of Irrigation 300
Power from Niagara Falls 305
Water-Power Resources and Installed Capacity of Water Wheels in the United States, by Census Divisions . . 306
The Water Power of the World 307
Floods and Their Prevention 313
Strategic River Locations 316
The Erie Canal and the New York State Barge Canal . . . 317
The Illinois and Michigan Canal 319
River and Canal Navigation in Europe and the United States 324
The Decline and Revival of Commerce on the Inland Waterways of the United States 332
Principal Commodities Shipped on the Great Lakes 335
"Soo" Canal Traffic 335
Shipments and Receipts of Freight at Principal United States Great Lakes Ports 336
Freight Shipments on the Mississippi River System and on the Great Lakes, 1916 336
Products of the Oceans 337
Strategic Ocean Locations 338
The Ice Patrol along Steamship Routes in the North Atlantic 342
Latitude and Longitude Determination on Shipboard . . . 346
The Environmental Background of Ports 347

PAGE

Value in Millions of Dollars of the Foreign Commerce of the Principal Ports of the World, 1913 355
Tides and Seaports 356
Map Projections 359
History of Car Ferry Transportation on Lake Michigan . . 361
Index 365

PART III. ILLUSTRATIONS

FIGURE

1. World-Map of Climatic Regions of the Continents
2. World-Map of Average Surface Temperatures for July
3. World-Map of Average Surface Temperatures for January
4. World-Map of Average Rainfall, May 1–October 31
5. World-Map of Average Rainfall, November 1–April 30
6. World-Map of Natural Vegetation
7. Major Land Forms of the Continents
8. World-Map of Density of Population
9. World-Map Showing Elevations of Land and Depths of Sea
10. World-Map of Political Divisions

11–46. Graphs of Average Monthly Temperature and Rainfall for Representative Stations

11. Para, Brazil
12. Hilo, Hawaii
13. Calcutta, India
14. Delhi, India
15. Ft. Lamy, French West Africa
16. Aswan, Egypt
17. Athens, Greece
18. Palermo, Sicily
19. Santiago, Chile
20. Los Angeles, Cal.
21. Shanghai, China
22. Charleston, S.C.
23. Austin, Tex.
24. Buenos Aires, Argentina
25. Portland, Ore.
26. Lille, France
27. Columbus, Ohio
28. Omaha, Neb.
29. Bukarest, Rumania
30. Peking, China
31. Winnipeg, Manitoba
32. Moscow, Russia
33. Harbin, Manchuria
34. Portland, Me.
35. Khiva, West Turkestan
36. Reno, Nev.
37. Wray, Colo.
38. Ft. Chipewyan, Canada
39. Point Barrow, Alaska
40. Victoria Land
41. Pangerango, Java
42. Darjeeling, India
43. Quito, Ecuador
44. La Paz, Bolivia
45. Mexico City, Mexico
46. Near Long's Peak, Colo.

47. Diagram Illustrating the Relation between Fahrenheit and Centigrade Temperature Scales
48. Diagram Illustrating the Relation between Inch and Millimeter Linear Scales
49. Diagram Illustrating the Relation between Feet and Meter Linear Scales

FIGURE

50. Diagram Illustrating the Relation between Mile and Kilometer Linear Scales
51. Diagram Illustrating the Relation between Acres and Hectares
52. Diagram Illustrating the Relation between Square Miles and Square Kilometers
53. A Clearing in the Rainy Low Latitude Forest of Eastern Bolivia
54. A Native Farm in a Slashing in the Rainy Low Latitude Forest of the Philippines
55. Rude Thatched House on a Native Farm in the Rainy Low Latitude Forest of Eastern Trinidad
56. Balls of Crude Rubber on the Dock at Para, Brazil
57. Picking Cacao on a Plantation in Costa Rica
58. Native Village on Stilts on a Rainy Low Latitude Coast, Celebes
59. Picking Plantation Bananas in Central America
60-65. Daily Maximum and Minimum Temperatures for the Coldest and Warmest Months at Selected Stations

60. Panama City, Panama, 1913
61. Arequipa, Peru, 1889
62. New Orleans, La., 1904
63. St. Louis, Mo., 1904
64. Winnipeg, Man., 1908
65. Victoria, B.C., 1904

66. Diagram Illustrating the Annual Revolution of the Earth about the Sun
67. Diagrams of the Earth Showing Variations in Sun Heating with the Seasons and with Latitude
68. Diagram Illustrating Latitudinal Variations in Sun Heating
69. A Section of Low Latitude Desert Devoid of Vegetation—the Libyan Desert
70. An Oasis in a Low Latitude Desert—the Nile Valley
71. The Scattered Vegetation of a Low Latitude Desert—the Thar
72. The Dry Season in a Teak Forest of Southwestern Coastal India
73. Hauling Mahogany in the Forest of the Wet-and-Dry Climate of Costa Rica
74. "Park" Vegetation on the East African Highland
75. Typical Vegetation on the Llanos
76. Setting Out Rice Plants in a Field near Madras, India
77. Rice Field Just before Harvest, near Madras, India
78. A Plantation of Rubber on the Malabar Coast, near Cochin, India
79. A Village on the Malabar Coast, South of Cochin, India

FIGURE
80. Irrigated Crops and Unirrigated Mango Groves Side by Side on the Upper Ganges Plain
81. Dry Season Crops, Irrigated from Wells, on a Well-Drained Alluvial Plain near Benares, India
82. Grain Sorghum near Nagpur, India
83. A River of the Wet-and-Dry Low Lattitude Climate during the Dry Season, East of Poona, India
84. Salt-Making on Sambhar Lake, Rajputana, India
85. Cutting Sugar Cane on a Plantation in Guadeloupe, West Indies
86. Deciduous Trees in a Pineapple Plantation in Western Cuba
87. Native Flora, Fauna, and Inhabitants of Kenya Colony, East Africa
88. Irrigation Agriculture on a Piedmont Plain on the Mexican Plateau
89. Young Coffee Plants among Felled Trees, Alta Vera Paz, Guatemala
90. Tea Plantations on Slopes in the Upland of Central Ceylon
91. Apples from the Kashmir Basin Ready for Shipment to the Lowlands of India
92. The Wool Market in Srinagar, Kashmir
93. Hand Sawing in a Timber Yard of the Eastern Himalayas
94. Tea under Slats in a Clearing in the Lowland Forest a Few Score Miles South of Darjeeling, India
95. An Anglo-Indian Bungalow, Punjab, India
96. Darjeeling, a Hill Station of Northern India
97. World-Map of Tropical Cyclones
98. World-Map of Wheat Acreage
99. World-Map of Rice Production
100. World-Map of Corn Acreage
101. World-Map of Potato Acreage
102. World-Map of Cotton Production
103. Map of Winter Wheat Acreage in Europe
104. Map of Spring Wheat Acreage in Europe
105. Map of Spring Wheat Acreage in the United States
106. Map of Winter Wheat Acreage in the United States
107. Map of Winter Wheat Acreage in Canada
108. Map of Cotton Acreage in the United States
109. Typical Vegetation of the Mediterranean Climate, Southern Greece
110. Harvesting the Olive Crop, Southern Greece
111. Irrigated Orange Grove in Southern California
112. Heaters in an Irrigated Orchard near Grand Junction, Colorado

FIGURE

113. Irrigated Rice Fields on a Floodplain, Southern Hunan Province, China
114. A Cotton Field in Georgia
115. Tea on Hill Slopes, Rice on Lowlands, Near Shidzuoka, Japan
116. A Method of Drying and Curing Rice in Spite of Rain-Soaked Fields, near Kyoto, Japan
117. Harvested Rice Hung in Trees to Dry. West Central China
118. Drying Rice Grains in the Damp Climate of Central China, Southern Hunan Province
119. Lifting Water on to a Rice Field, near Canton, China
120. Water Buffalo Plowing a Rice Field in Central China
121. Low Water in the Siang River, Hunan Province, China
122. A Clearing in Luxuriant Forest on the Shore of Lago Nahuel Huapi, in Mild-Winter–Mild-Summer Climate of the Southern Andes
123*a*. Forest in Western Washington, Characteristic of the Mild-Winter–Mild-Summer Type of Climate
123*b*. Logging in the Dense Forest of the Pacific Northwest
124. Dairy Herd and Luxuriant Pastures of Western Ireland
125. Shocks in a Wheat Field of the Red River Valley
126. "Hogging Down" Corn in the Corn Belt of North Central United States
127. Map of the United States, Showing the Season Available for the Growth of Crops in Four-Fifths of the Years
128. A Cultivated Plain Planted to Kaoliang and Beans in the Humid Continental Climate with Long Summers, near Mukden, Manchuria
129. Map of Counties in Southeastern United States Which Lead in Shipments of Early Potatoes
130. Map Showing Distribution of Early Potatoes from Hastings, Florida
131. Winter Landscape in Chicago
132. Summer Landscape in Chicago
133. Snow Plow on the Michigan Central Railroad in Northern Michigan
134. Cutting Ice on Lake Calumet, Chicago
135. A Tornado Cloud at Solomon, Kansas
136. Destruction Wrought by a Tornado at Charleston, Illinois
137. Graph Showing by Months the Number of Hours Artificial Light Is Used Daily in Chicago
138. Map Showing the Average Number of Days Per Year with Dense Fog in the United States
139. The Desert at the Eastern Base of the Sierra Nevada Mountains

FIGURE

140. Map of Average Annual Precipitation in Northwestern United States
141. Map Showing Land in Harvested Crops in the United States, 1919.
142. Map Showing Irrigated Land in the United States
143. Sheep Grazing near a Water Hole in Semi-arid Northern Patagonia
144. Cattle Grazing on the Semi-arid Plains of Western United States
145. Flock of Sheep on the Semi-arid Grasslands of Southeastern Mongolia
146. An Encampment of Khirghiz Nomads, Western Asia
147. A Part of the "Great Wall" of China
148. A Camel Caravan Northwest of Kalgan, China
149. Irrigated and Unirrigated Lands in Yakima Valley, Washington
150. Map Showing Distribution of Rainfall over the Continents and the Oceans
151. Diagram of Wind Directions in High- and Low-Pressure Areas in the Northern Hemisphere
152. Vertical Cross-Section Diagram to Show Circulation of Air in High and Low Pressure Areas
153. Diagrammatic Weather Map Typical of Northern Hemisphere Conditions
154. Average Paths of Lows in the United States and Southern Canada
155. Wind Directions at Baltimore, Maryland
156–64. Daily Weather Maps of the United States

156. March 29, 1923
157. March 30, 1923
158. March 31, 1923
159. July 28, 1916
160. December 27, 1894
161. December 28, 1894
162. December 29, 1894
163. October 9, 1919
164. October 10, 1919

165. A Tourist Hotel amid Grand Mountain Scenery, Banff, Alberta, Canada
166. Winter Aspect of St. Moritz, an All-Year Resort in the Swiss Alps
167. Map of Forest and Woodland in the United States
168. Map of Potential Use of the Land in North America
169. Map of National Forests in the United States
170. Cattle and Stone Huts on a High Summer Pasture in Switzerland
171. Map of Cultivated Areas in the Central Tyrolean Alps

FIGURE
172. Hay Land in Estes Park (Colorado), at an Altitude of ca. 7,500 Feet
173. Snow Fences Erected to Protect a Railroad Track in Mountains. Boreas Pass, Colorado
174. The Northern Edge of the Canadian Forest
175. Map of the Zone Inhabited by Eskimos on the Advent of White Men
176. Reindeer Grazing on the Tundra of the Lower Yenisei River, Siberia
177. Dog Train of Sledges on the Artic Border of Canada. Winter
178. Skin Tents of Eskimos on the Arctic Coast of Canada. Summer
179. An Eskimo Fishing from a Native Canoe
180. Skiing and Sledging in Spitzbergen. Winter
181. A Terraced Mountain Slope in the Outer Himalayas near Darjeeling, India
182. Cultivated Valley Floor in the Andes of Southern Peru
183. Terraced Lower Slopes of a Cone of Alluvial Material in the Valley of the Jhelum, Outer Himalayas, Northwestern India
184. The Highly Cultivated Intermontane Basin of Kashmir
185. The Bernina Alps South of St. Moritz, Switzerland
186. The Valley of the Bonne, a U-Shaped, Ice-Scoured Valley in the French Alps
187. Cirque, Partly Occupied by Grinnell Glacier and Grinnell Lake, Glacier National Park, Montana
188. A Western Fiord of Lago Nahuel Huapi, Southern Andes
189. Lago Nahuel Huapi, Southern Andes, with Its Morainal Dam and Glacial Outwash in the Foreground
190. Map of Typical Features Produced by Mountain Glaciation. Eastern End of Lago Nahuel Huapi, Southern Andes
191. Map of Distribution and Extent of Former Glaciers in the Southern Andes of Argentina
192. The Partially Eroded Volcanic Cone of Mount St. Helens, Washington
193. The Volcanic Cone of Osorno, Southern Chile
194. Transportation Routes in a Narrow Mountain Valley. Ogden Canyon, Wasatch Mountains, Utah
195*a*. Railroad Climbing to Marshall Pass, Colorado
195*b*. Plowing on the Plains of New South Wales, Australia
196. Map of Railroads in the United States, 1917
197. A Valley in the Schwarzwald Hill Country, Southwestern Germany
198. A Scene in the Schwarzwald, Southwestern Germany, Showing a Typical Farmstead

FIGURE
199. Use of the Land in the Hill Country of Eastern Kentucky
200. Hill Country of Eastern Kentucky, Covered with Deciduous Forest
201. A Farmstead in the Hill Country of Eastern Kentucky
202. Corn in a Forest of Girdled Trees, on a Steep Slope in the Hill Country of Eastern Kentucky
203. The Hill Country of Western Chili Province, China
204. Hill Country Where Terracing Is Facilitated by a Deep Mantle of Loess. Near Taiyuan-Fu, Shansi Province, China
205. A Farmstead in the "Valley of East Tennessee."
206. The Canyon of the Yellowstone River
207. The Grand Canyon of the Colorado River
208. The Illinois River and Its Floodplain, near Starved Rock, Illinois
209. A Stretch of the Ganges River and Its Floodplain, near Agra, India
210. The Mississippi River and Its Floodplain a Few Miles below the Mouth of the Wisconsin River
211. The Wisconsin River and Its Floodplain, near Mazomanie, Wisconsin
212. Map of the Lower Course of the Tisza River, Hungary, Showing Reclamation of Flood Areas
213. Map of the Outer Margin of the Mississippi Delta
214. Native Barge of Hay on the Hugli River, a Distributary of the Ganges
215. Map of Land Holdings on the Mississippi Delta a Few Miles above New Orleans
216. The Mississippi River in Flood, a Stretch of Levee, and a Bayou, a Short Distance above New Orleans
217. A Knoll of Refuge during a Flood of the Mississippi River, Arkansas
218. Flood Refugees on Levee of Lower Mississippi River
219. The Levee at New Orleans, with a Flooded Wharf and a Street below the Level of the River
220. World-Map Showing the Location of Extensive Deltas
221. The Lower Ganges River as It Flows through Its Low, Flat, Delta Plain
222. Rice Fields on the Ganges Delta
223. Map of the New Orleans Drainage System, 1922
224. Pontoon Bridge across River at Calcutta, India
225. The Pampas of Argentina
226. Geographic Cross-Section of a Part of the San Bernardino Mountains and the Associated Piedmont Plain, Southern California

FIGURE
227. Map of Land Utilization on the Piedmont Plain in the Vicinity of Ontario, California
228. Cultivated Land on the Lower Piedmont Plain, South of Ontario, California
229. "Raw Land" on the Upper Piedmont Plain, near Upland, California
230. The Piedmont Plain at the Base of the Wasatch Mountains, Utah
231. Orange Groves on the Upper Piedmont Plain, near San Bernardino, California
232. Map of Land-Form Divisions of the United States
233. Map of Undrained Wet Land in the United States, 1919
234. Vegetables on a Drained Marsh of the South Atlantic Coastal Plain of the United States
235. Map of the Zuider Zee Drainage Project, The Netherlands
236. Map of a Part of the Low Countries, Showing the Polder Land
237. Sand Dune Advancing upon a Forest, near Sawyer, Michigan
238. Planting Beach Grass to Hold Dunes on Cape Cod, Massachusetts
239. An Alluvial Plain at the Head of Kagoshima Bay, Kyushyu, Japan
240. World-Map of Areas Glaciated So Recently as to Affect Their Utilization
241. Map of the Ice-Scoured Areas of Northeastern North America
242. Diagrammatic Cross-Section of an Ice-Scoured Plain
243. Characteristic Features of the Southern Part of the Ice-scoured Plain of North America
244. Diagrammatic Cross-Section of a Moraine Plain
245. An Exposed Face of Glacial Till, a Score of Miles East of Lago Nahuel Huapi, Argentina
246. Moderately Rolling Moraine in a Farming District. Southern Wisconsin
247. Plowing Flat Moraine Plain in Northeastern Illinois
248. Moderate Rolling Moraine Area with Many Depressions, Southern Wisconsin
249. Rough Moraine in a Farming District near Chicago
250. Gullied Farm Land in Moraine Country. Northeastern Iowa
251. A Bowlder-Strewn Moraine Plain near Chisholm, Minnesota
252. Map of Land in the United States Artificially Drained, 1919
253. Map of Ice-scoured, Younger Morainal, and Older Morainal Areas in East Central North America
254. Map Showing Deposits of Glacial Outwash in Middle Western United States

FIGURE
255. Cross-Section of the Illinois Valley through Ottawa, Illinois
256. Map of Glacial Outwash in Southern Wisconsin and Northern Illinois
257. Beds of Stratified Sand and Gravel in Glacial Outwash near Sauk, Wisconsin
258. A City Located on a River Terrace. Heidelberg, Germany
259. Plowing on the Lake Agassiz Plain
260. A Railroad on the Lake Agassiz Plain
261. Map Showing the Area Covered by Glacial Lake Agassiz
262. Map of Surface Materials at the Edge of the Lake Agassiz Plain
263. Map Showing Glacial Lacustrine Plains about the Great Lakes
264. Map of the Principal Lacustrine Plains of the Great Basin, Western United States.
265. The Plain of Residual Soils near Lancaster, Pennsylvania
266. Soil Map of Lancaster-Lebanon, Pennsylvania, Area
267. A Farmstead in the Piedmont Area of Residual Soils, South of Washington, D. C.
268. The Bluegrass of Kentucky
269. Thin Residual Soil Showing Outcrops of Bedrock. The Valley of East Tennessee
270. Farm Land Destroyed by Gullying. The Valley of East Tennessee
271. Soil Map of a District on the Moraine Plain About Troy Grove, Illinois
272. A Ruined Church in Guatemala City, after the Earthquake of June, 1918
273. Destruction Wrought by the Earthquake of September, 1923, at Tokyo, Japan
274. World-Map Showing the Areas on the Continents Subject to Recurrent Earthquakes
275. Railroad Tracks Twisted by the San Francisco Earthquake of 1906
276. Earthquake Destruction in Tokyo, Japan, September, 1923
277. The Destroyed City of St. Pierre, Martinique, after the Eruption of Mount Pelée in 1902
278. Terraced Fields Buried under Infertile Volcanic Ash. Sakuragima, Japan
279. Quarry in Limestone, from Which Building Blocks Are Being Taken, near Milwaukee, Wisconsin
280. Quarry in Limestone, near Chicago. The Rock Is Crushed for Use in Roadmaking, Concrete, and Fertilizer.
281. Pit-Head of a Coal Mine in the Hill Country of Eastern Kentucky
282. World-Map of the Chief Coal-Producing Districts

FIGURE
283. World-Map of the Chief Iron Ore–Producing Districts
284. Map Showing the Relation of Cities to Coal Fields in the British Isles
285. Surface Mining of Manganese near Nagpur, India
286. Stripping Glacial till off Iron-Ore Deposits at Hibbing, Minnesota
287. Map Showing the Movement of Iron Ore on the Great Lakes
288. Pit-Head of a Coal Mine in the Farming District of Central Illinois
289. Cross-Section of Coal Seams in Pennsylvania Anthracite District
290. A Mining Community in the Desert. Tonopah, Nevada
291. Cross-Section of a Gold Mine about 30 Miles West of Denver, Colorado
292. Hydraulic Mining of Tin in the Malay Peninsula
293. Petroleum Field in Southern California
294. Cross-Section Showing Typical Occurrence of Petroleum and Natural Gas
295. Diagrammatic Cross-Section Showing the Relation between the Surface of the Earth and the Ground-Water Surface
296. Diagrammatic Cross-Section Showing Safe and Unsafe Wells
297. Cross-Section from the Black Hills to the Missouri River, Showing Artesian Water Conditions
298. Horizon of Springs along the Line of Contact between Rock Strata
299. A Farm in Semi-arid Northern Patagonia, Irrigated from a Hill-side Spring
300. Diagrammatic Cross-Section of a Spring at the Contact between Pervious and Impervious Glacial Material
301. Map of Ground-Water Provinces of the United States
302. Map of the Water-Supply System of San Francisco, California
303. Map of the Water-Supply System of St. Louis, Missouri
304. Reservoir of the San Francisco Water System, Hetch Hetchy Valley
305. Map of the Water-Supply and -Sewage Disposal Systems of Chicago, Illinois
306. Map of the Chief Areas Irrigated from Canals in India
307. Hand Irrigation from a Well on the Ganges Plain, near Cawnpore, India
308. The Ganges River at the Front of the Himalayas, and the Diversion Works of the Upper Ganges Canal
309. Map of the Diversion Works of the Upper Ganges Canal
310. The Aswan Dam on the Nile River, Egypt

FIGURE
311. Irrigation Canal Lined with Concrete. Newlands Reclamation Project, Nevada
312. Map of United States Government Irrigation Projects
313. Map of the Salt River Reclamation Project, Arizona
314. Roosevelt Dam, Salt River Reclamation Project
315. Irrigating a Field, Uncompahgre Reclamation Project, Colorado
316. Diversion Dam and Canal, Strawberry Reclamation Project, Utah
317. Pumping Plant to Lift Water from a Canal at River Level to a High-Level Canal, Grand Valley Reclamation Project Colorado
318. Irrigation Canal High on the Side of a Valley, Yakima Project, Washington
319. Variations in the Volume of Flow of Boise River, above Boise, Idaho, from January, 1895, to December, 1896
320. A Typical Mountain Stream in the Rainy Southern Andes of Chile, Latitude 40° S.
321. Hydroelectric Plant at Long Lake, Washington
322. Hydroelectric Power Development at Shoshone Falls, Idaho
323. Hydroelectric Plant at the Des Moines Rapids of the Mississippi River, Keokuk, Iowa
324. Hydroelectric Power Applied to Railroad Transportation in the Mountains of Western United States
325. Niagara Falls and a Part of Its Hydroelectric Development
326. A Mississippi River Steamboat
327. Grain Elevator and Warehouse, Built and Much Used during the Days of Active River Commerce, Prairie du Chien, Wisconsin
328. A Large Junk Used in the Yangtze River Trade
329. The River Front at Canton, China
330. Shipping at the Confluence of the Han and Yangtze Rivers, Hankow, China
331. Men Towing a Boat through the Rapids at the Lower End of the Gorges of the Pei River, South China
332. Barge Traffic on the Rhine above Coblenz
333. Log Rafts on the Kushiro River at Kushiro, Hokkaido, Japan
334. Map of Principal Canals Constructed in the United States, before 1875
335. Map of the Illinois and Michigan Canal
336. Lock on the Illinois and Michigan Canal
337. Map of Principal Canals and Navigable Rivers in North Central Europe
338. A Fleet of Modern Barges on the Mississippi River
339. Steamer Loading at Ore Docks at Duluth, Minnesota
340. Map of Car Ferry Lines Crossing the Great Lakes

FIGURE
341. Map Showing World Distribution of Herring
342. World-Map of Surface-Water Temperatures of the Oceans for February
343. World-Map of Surface-Water Temperatures of the Oceans for August
344. Map of Fog and Icebergs in Early Summer near North Atlantic Steamship Lanes
345. Diagram Illustrating the Effect of Wind on the Course Followed by a Ship Kept Constantly Headed in the Same Compass Direction
346. Map of General Drift of Icebergs from Greenland to the Grand Banks
347. World-Map of Sailing Vessel Routes for Midsummer in the Northern Hemisphere and Midwinter in the Southern Hemisphere
348. Diagram Illustrating the Use of the Sextant
349. Diagram Illustrating the Application of Sextant Readings to the Determination of Latitude
350. Diagram Showing Time on Selected Meridians When It Is Noon at Greenwich, England
351. World-Map of Standard Time Zones and the International Date Line
352. New York Harbor from the Air
353. Boston from the Air
354. Fiord Harbor of Svolvaer, Norway
355. Map of the Coast of British Columbia, near the Mouth of the Skeena River
356. Wheat Awaiting Shipment at Karachi, India
357. Ships at Anchor off the Harborless Coast at Iquique, Chile
358. Lowering Passengers from Steamer to Lighter off the Harborless Coast of Costa Rica
359. The Harborless Coast Line at Madras, India
360. Part of the Artificial Harbor at Madras, India
361. Map of Harbor Works and Made Land at Madras, India
362. Map of the Harbor of Galveston, Texas
363. Map of the World on Mercator's Projection
364. Map of the World on Goode's Homolosine Projection
365. Map of the World on Mollweide's Homolographic Projection
366. Eastern Kentucky Hillside Coal Mine

SUGGESTIONS TO STUDENTS AND TEACHERS

ORGANIZATION AND USE OF THE BOOK

An Introduction to Economic Geography is intended as a survey of the subject for students in their first year at college or their later years in high school. Volume I deals with the natural environment in its bearing on man's economic life, and Volume II treats of the major economic activities as related to the natural environment. Together these volumes are calculated to cover the principal facts of world economic geography, and to establish the fundamental principles of the science. Thus, while presenting a bird's-eye view of the whole subject to students who do not intend to pursue it farther, this book also lays solid foundations for more detailed and advanced study of economic geography, and for the whole elaborate superstructure of social, political, historical, and regional geography. The authors conceive the working out of the relations between natural environment and human life in the various regions of the earth to be the primary business of the geographer. Therefore explanation of the *origin* of the natural environment has purposely been excluded, except where it clearly helps the student to understand life-relations to the environment. It is felt that a comprehensive treatment of causes of climate, and of origins of land forms and soils, while a necessary part of the training of the professional geographer, is out of place in an elementary textbook.

The following paragraphs of suggestions cover Volume I: *Natural Environment as Related to Economic Life*, and both student and teacher should refer to them as occasion arises.

The material of this volume is subdivided into topics, each of which covers a single phase of one of the environmental elements, e.g., "The Rainy Low Latitude Type of Climate," "Lacustrine Plains," "Streams for Power." For the sake of coherence these topics are grouped into chapters, each of which comprises a survey of a single environmental element or of inextricably related environmental elements, e.g., "Minerals," "Climate and Natural Vegetation." The volume as a whole is intended to cover in sequence the types of each environmental element which are of importance to mankind, to establish their distribution, and to indicate specific ways in which these earth conditions and earth

resources bear upon human life, more especially economic life. Regional geography is the goal which has been constantly in mind during the preparation of this introductory study, for the authors believed that the ultimate objective of all geographic study should be an understanding of the relations between human life and the natural environment *in regions*.

The core of the book is the series of exercises (Part I), and the kernel of each topic is embodied in the questions set for that topic. In taking up the study of a topic the student is expected to work through the appropriate exercise, *answering to the best of his ability each question before passing on to the next.* References to maps, diagrams, photographs, and textual materials are inserted at the points where their use will facilitate solution of the problems. This study of the questions will lead the student into and through his preparation. It will give him training in investigating, correlating, and assimilating data; it does not give him mental provender predigested. The illustrations are even more important in this study than the textual materials. Therefore users of the book are cautioned against relying on the text matter for answers to the questions. The geographic facts to be gleaned from a study of the photographs are suggested in the questions rather than in the accompanying titles, which are given chiefly for purposes of identification.

The number of questions under a given topic varies with its character rather than with its importance. In some cases a few questions bring out the salient aspects of a very important subject, whereas a much less important topic may require many questions. In much the same way a few lines of text may illuminate a major subject, whereas a minor point may require several pages. A rough measure of the amount of time which first-year college classes have been found to require for each exercise is set up in the "Time Schedule" below.

Most of the questions fall into one of three classes.

a) Those which the student is expected to answer specifically from his general store of knowledge, or after studying materials to which reference is made, i.e., questions of fact, such as 2 and 10 in the exercise on the "Rainy Low Latitude Climate" (pp. 6–7).

b) Those which involve correlation of the different materials referred to, or of new matter with facts or principles previously established, i.e., questions of reasoning, such as 4 and 6 in the exercise referred to. Answers to this type of question should be as exact as

those to questions of fact, but more than one line of reasoning may be equally correct.

c) Those which are to be answered tentatively, from the student's general store of knowledge, including increments derived from this study, i.e., questions of hypothesis, such as 5 in the exercise referred to. Most of the questions of this category are introduced by some such phrase as "Do you suppose?"

The teacher who wishes to insert additional questions may do so without fear of violating the continuity of the exercises.

The organization of the topics in class meetings must vary with the maturity and caliber of the students, with the amount of class time available, with the size of the class, and above all, with the individuality of the teacher. Almost any coherent scheme which appeals to the teacher may safely be adopted, *except the habitual practice of repeating the questions in the exercises.* Students who have conscientiously worked through the exercises will be bored by a repetition of those questions. On the other hand they will be eager to absorb supplementary facts and corollary principles. In the case of topics which the teacher can amplify from first-hand information gleaned in travel, descriptive lecture is desirable, either with or without lantern slides. Where a laboratory is available for the use of extra maps and photographs, studies of specific examples of the type of environment under consideration may be elaborated without end. In other cases a question at the beginning of a class period, calculated to bring out a fundamental principle of geography, will usually bear fruit in a discussion both profitable and interesting to the students. The teacher who enters the classroom with ten or a dozen such questions will rarely be able to cover them in a fifty-minute period, so numerous and vital are the ramifications of each.

The work of the class is greatly facilitated by conferences with small groups (not more than eight). These should be arranged whenever a new topic requiring technical proficiency is broached. Thus the second day may profitably be spent in showing the use of the atlas, the illustrations, and the texts. Conferences should also be arranged for the first exercise involving weather maps and for the introductory study of topographic maps.

In conference the student should be asked questions which will bring out (*a*) the meaning of the symbols on the maps or diagrams, and (*b*) the significant geographic facts which can be deduced from a given type of map, graph, or illustration.

Without such conferences, some members of the class will inevitably fail to grasp certain topics for which an understanding of these special materials of geography are fundamental.

TIME SCHEDULE

The approximate number of class periods required for each topic and the percentage of the total time of the course required by each chapter are estimated in the following table. The estimates are based on a term of fifty-five days (five days a week for eleven weeks or three days a week for eighteen weeks) and class periods fifty minutes in length. They take no account of time spent in field trips, in laboratory, or in the final examination.

CHAPTER	TOPIC	NUMBER OF PERIODS
I.	THE SCOPE OF ECONOMIC GEOGRAPHY	1
	Two per cent of the total class time. This topic is intended to be discussed at the first class meeting without previous study.	
II.	CLIMATE AND NATURAL VEGETATION	
	Thirty-eight per cent of the total class time.	
	Rainy Low Latitude Type of Climate	2
	This exercise is not more important than the next, but extra time is allotted to it in order that the instructor may make sure that each student is learning how to recognize significant facts, to work out logically the relations between economic life and natural environment, and to make effective use of the materials—maps, graphs, diagrams, photographs, text, atlases.	
	Low Latitude Desert Type of Climate	1
	Wet-and-Dry Low Latitude and Semi-arid Low Latitude Types of Climate	2
	Climates of Higher Altitudes in Low Latitudes	1
	Review of Low Latitude Types of Climate	½
	The student should be allowed two or three days for careful preparation of written answers to the questions in this exercise.	
	Middle Latitude Climates	½
	A few minutes devoted to contrasting low latitude climates with those of middle latitudes will serve to introduce the student to the new problems of the next topics.	
	Climate of West Margins of Continents in Lower Middle Latitudes, Dry Subtropical Climate	1
	Climate of East Margins of Continents in Lower Middle Latitudes, Humid Subtropical Climate	1
	Climate of West Margins of Continents in Higher Middle Latitudes, Mild-Winter–Mild-Summer Climate	1

CHAPTER	TOPIC	NUMBER OF PERIODS
	Humid Continental Climates with Long Summers and with Short Summers	2
	Climate of East Margins of the Continents in Higher Middle Latitudes, Modified Humid Continental Climate	1
	Middle Latitude Desert Climate	1
	Semi-arid Middle Latitude Climate	1
	The Variable Weather of the Middle Latitudes (three exercises)	4
	Most students find the study of weather difficult, and require a day for review, in addition to the day allotted to each exercise.	
	Climates of Higher Altitudes in Middle Latitudes	1
	High Latitude Climates	1
	A review examination on types of climate is appropriate at this point. Emphasis in this examination should be laid on the middle latitude types, but comparisons should be made with both low latitude and high latitude types.	
III.	LAND FORMS AND SOILS	
	Thirty-three per cent of the total class time.	
	Comparison between Land Forms, Soils, and Climate	1
	Major Land Forms	½
	Mountains	1½
	Topographic maps are introduced in this and following exercises. Time should be taken to see that each student understands how to read such maps.	
	Plains	1
	Hill Country	1
	Plateaus	1
	Minor Land Forms	½
	Flooded Alluvial Plains (Valley Floodplains and Delta Plains)	1½
	Well-drained Alluvial Plains	1
	Piedmont Alluvial Plains	1
	Coastal Plains of Unconsolidated Marine Sediments	1
	Ice-scoured Plains and Hill Country and Moraine Plains	2
	Plains of Glacial Outwash	1
	Lacustrine Plains	1
	Plains Having Residual Soils	1
	Soils	1
	Earthquakes and Volcanic Eruptions	1
	At this point an entire class period may well be devoted to a written examination on land forms and soils.	
IV.	BED ROCK AND MINERAL DEPOSITS	
	Four per cent of the total class time.	
	Bed Rock as an Element of the Natural Environment	1
	Mineral Deposits	1

CHAPTER	TOPIC	NUMBER OF PERIODS
V.	GROUND AND SURFACE WATERS OF THE LANDS	
	Sixteen per cent of the total class time.	
	Ground Water and Its Uses	1
	Streams and Lakes as a Source of City Water Supply	½
	Streams for Irrigation	2
	Streams for Water Power	1½
	Rivers as Commercial Highways	2
	Great Lakes and Inland Seas as Highways	1
	An oral quiz on the materials of chapters iv and v is suggested at this point. By this time the student should be clear as to the interrelations among the several elements of the natural environment.	
VI.	OCEANS AND THEIR COASTS	
	Five per cent of the total class time.	
	The Oceans	1
	Coast Lines and Harbors	2
VII.	SHAPE, SIZE, AND LOCATION AS ELEMENTS OF THE NATURAL ENVIRONMENT	
	Two per cent of the total class time	1

THE PLACE OF FIELD WORK IN ECONOMIC GEOGRAPHY

Field work is essential in the study of economic geography. Direct observation of (*a*) economic conditions, (*b*) the natural environment, and (*c*) the relations between (*a*) and (*b*) should constitute an important part of a course such as this book outlines. Field trips help greatly in making geography tangible to the student, and they are a great stimulus to the powers of observation.

Experience has shown that field trips may either precede or follow classroom discussion of most topics. At the University of Chicago, for example, although the same order of classroom discussion is followed with both Autumn Quarter and Spring Quarter classes, the field trips in the autumn come early and in the spring late, in order to take advantage of favorable weather.

It should be remembered that on these introductory field excursions the whole realm of geographic observation, analysis, and philosophy cannot be taught. A few outstanding points made emphatically and interestingly and thoroughly are better than many ideas incompletely presented. Quizzing should be alternated with lecturing, and at the close of the trip the important features studied should stand out

clearly and in orderly fashion in the student's mind. In some cases it is desirable to have a brief class discussion before the trip, and in most cases afterward also, the former by way of preparation, the latter by way of summarizing conclusions. All trips should be reported by the student in writing. At the close of each trip, the instructor may announce a definite topic for a brief paper, the topic being so chosen as to bring out the chief points made on the trip; or the student may be asked to write a term report on the whole season's work, correlating observations of similar phenomena observed on the different trips.

Above all, field work should be made attractive. Students will get more out of trips that are enjoyable than those that are boresome. If the excursion is to take all day, a pail, coffee, sugar, and condensed milk should be taken so that a hot drink can be had around a midday camp fire. Students should be cautioned beforehand to wear comfortable shoes, and clothes that will not suffer from field service. Most students are unused to much walking. Experience has shown that a rate of not more than 2 or $2\frac{1}{2}$ miles per hour should be maintained, and this for not more than 4 to 6 miles for a half-day trip, or 8 to 10 miles for an all-day trip. The party should assemble quickly each time a stop is made, and careful attention should be paid to discussions; otherwise much time will be wasted.

Sets of questions studied on trips taken by classes at the University of Chicago may be obtained from the publishers. They illustrate the type of work that can be developed in any locality. The geographic items to be seen in different areas vary greatly, but the ultimate goal as stated in the first paragraph of this section remains unchanged. Questions and suggestions similar to those noted above should be worked out for the district accessible to a particular school and put in the hands of each student before the trips. Wherever government topographic maps are available they should be used. Where such maps have not been made, county post-road maps[1] or other large-scale maps are available in most cases. A map of the whole district, showing the relation of the locality where the field work is to be done to other parts of the area, should be posted before the trips are taken. This enables the student to relate what he is seeing to other items that he has seen or knows about.

[1] Issued by the Post-Office Department, Washington, D.C.

MATERIALS FOR GEOGRAPHIC STUDY

The materials for geographic study are voluminous and varied. An attempt has been made to incorporate in this volume everything indispensable to the course which it covers, except an atlas. Goode's *School Atlas* (Chicago: Rand McNally & Co., 1923) or Philip's *Modern School Atlas* (London: George Philip & Son, 1922) are adequate to the needs of the college or high-school student. Atlases and textbooks should be brought to class daily, in order that constant reference to maps and photographs may be made as the discussion proceeds. It should never be forgotten that a photograph will often convey a more real and detailed impression than pages of text or lengthy oral expositions, and that few persons, if indeed any, can intelligently follow a discussion involving distributions without the aid of a map before their eyes.

Several of the maps to be used with the book are printed on loose sheets and placed in a map pocket. This arrangement facilitates coloring, and permits the student to spread out several maps for purposes of comparison. Coloring the maps bit by bit, as directed in the exercises, helps the student to gain an accurate knowledge of places, without which he is adrift in an uncharted sea of facts. The coloring can be done accurately and neatly without consuming an undue amount of time, if a good grade of pencils is used and if the color is applied lightly from a long point. In coloring large areas the pencil should be held almost parallel to the paper. Extra sets of these maps and individual maps may be obtained from the publisher.

In addition to textbook and atlas, a useful permanent collection of supplementary materials may be acquired by the school to the extent of its facilities and finances.

The exercises contemplate possession by the school of certain topographic maps, which are posted where they can be used by the class. They can be purchased, in quantity at six cents apiece, from "The Director, United States Geological Survey, Washington, D.C." Editions with woodlands printed in green should be specified in all cases where they have been published. When mounted on cloth maps resist wear indefinitely. Where several adjoining maps of the same scale are used it is desirable to have them mounted to form a single map. This may be rolled on sticks or folded (if cut before being mounted) and stored in a drawer or a vertical filing cabinet.

The topographic maps required in the exercises are referred to as

need for them arises. The following complete list is inserted to facilitate ordering.

Arizona
- Camelsback
- Chino
- Desert Well
- Echo Cliffs
- Florence
- Fort McDowell
- Gila Butte
- Kaibab
- Maricopa
- Mesa
- Phoenix
- Roosevelt
- Sacaton
- San Francisco Mountains

California
- Cucamonga

Delaware
- Cape Henlopen
- Cedar Creek
- Millsboro
- Rehoboth

Illinois
- Calumet
- Chester
- Chicago
- Desplaines
- Galena
- Joliet
- La Salle
- Marseilles
- Morris
- Ottawa
- Riverside
- Wilmington

Iowa-Wisconsin
- Elkader
- Waukon

Kentucky
- Georgetown
- Paintsville

Louisiana
- Barataria
- Bodreau
- Bonnet Carre
- Cat Island
- Chandeleur
- Chel Menteur
- Cheniere Caminada
- Creole
- Cut Off
- Dime
- Dulac
- East Delta
- Fort Livingston
- Forts
- Hahnville
- Houma
- Lac Des Allemands
- La Fortuna
- Lake Felicity
- Mount Airy
- Natches
- New Orleans
- P. a La Hache
- Quarantine
- Rigolets
- St. Bernard
- Shell Beach
- Spanish Fort
- Timbalier
- Toulme
- West Delta

Maryland
- Baltimore
- Gunpowder
- North Point
- Relay

Massachusetts
- Boston and Vicinity
- Provincetown
- Wellfleet

Michigan-Indiana
- Three Rivers

Minnesota
- Anoka
- Herman
- Minneapolis
- Pelican Rapids
- St. Paul
- Vergos
- White Bear

Missouri
Eminence

Nevada
Carson Sink

North Carolina–South Carolina
Charlotte

New York–New Jersey
New York City and Vicinity

Ohio
Findlay

Pennsylvania
Harrisburg
Lancaster

Tennessee
Murfreesboro

Washington
Chiwaukun
Skykomish

Wisconsin
Lancaster (Wis.–Ia.–Ill.)
Neshkoro
Ripon

Other topographic maps than those called for in the exercises can be obtained for many parts of the United States. Index sheets of the several states, showing areas mapped, can be obtained free by applying to the Survey.

It is a great help to the students in mastering the reading of topographic maps if copies for each student or each two students are available for use at the first two or three class sessions on major land forms.

Additional materials which are helpful in geographic study are the following:

a) A globe of 12-inch diameter or larger. Globes are made by the principal map-makers. In this country they can be procured from Rand McNally & Co., Chicago; A. J. Nystrom & Co., Chicago; Denoyer-Geppert Co., Chicago.

b) A large atlas. By all odds the most useful is the *Times Survey Atlas of the World, Selfridge Edition.* (London: The Times, 1922.)

c) Wall maps of each of the continents as follows:

Philip's Rainfall, November-April
Philip's Rainfall, May-October
Philip's Natural Vegetation
Philip's Population
} (Denoyer-Geppert Co.)
Goode's Relief (Rand McNally & Co.)
Haack's Relief (Denoyer-Geppert Co.)

d) Relief models of the continents and of smaller units. These are made by E. J. H. Lorentz, Madison, Wisconsin, and Robertson Bros., Washington, D.C.

e) Outline desk maps of the world, of continents, and of smaller units, for use by students. Among the most useful series are Goode's (University of Chicago Press, Chicago), Ridgeley's (McKnight &

McKnight, Normal, Illinois), and those issued by A. J. Nystrom & Co., Chicago, and by Denoyer-Geppert Co., Chicago.

f) Outline weather maps to be used in the exercises on weather. Order "Station base maps" at 25 cents per hundred from Chief, United States Weather Bureau, Washington, D. C.

g) "Time-Zone Chart of the World," sold as Chart No. 5192 by the Hydrographic Office of the United States Navy Department, Washington, D.C., for 20 cents.

h) Photographs and smaller maps. Valuable or irreplaceable materials of this character should be posted only under glass. They can be passed around in small classes or in laboratory groups, but in large classes they tend to confuse and divert the interest.

i) Stereographs.

j) Stereopticon slides serve as a means of showing pictures and maps. As a rule each teacher must build up his own collection. Occasionally a geographic movie may be rented.

PART I

EXERCISES

CHAPTER I

THE SCOPE OF ECONOMIC GEOGRAPHY[1]

The earth is the stage on which men live and work. The broad limits within which economic life functions, therefore, are set by the natural environment. In any given region there is a variety of economic pursuits in which men may engage successfully, but in the same region there are numerous other pursuits in which success is out of the question. Among the conditions which have a bearing on the economic life of a region none is more fundamental than the natural environment, none changes so little from generation to generation even though succeeding generations make very different uses of it, and none varies more from region to region. It is the purpose of economic geography to investigate for the various regions of the earth the relation between economic life and the natural environment.

Economic geography shares with other branches of knowledge—economics, agriculture, geology, history—the responsibility of studying economic life. The peculiar contribution of economic geography is an understanding of the relation between natural environment and economic life in the various regions of the earth. Formerly men observed regional differences, such as the fact that there were many people in some regions and few in others, or that certain crops were raised in some regions and quite other crops in other regions, and were content to stop with these observations, or with some fantastic explanation. In recent times, however, men have come to search for the causes of these regional differences in economic life. Such knowledge is inherently interesting. It is also essential if wise use is to be made of the natural possibilities of any given area. The more wisely the natural resources of all regions are used the higher can be the material standard of living of all mankind.

This book endeavors to establish fundamental principles of economic geography through the study of actual conditions in many parts of the earth. In Volume I of the book the elements of the

[1] Suggestions for using this book may be found in the front of this volume, pp. xxvii–xxxvii.

natural environment are considered, with a view to distinguishing *types*. For each type, whether it be of climate or of land forms or of some other element of the natural environment, the aim is to determine (*a*) its characteristics, (*b*) its regional distribution, and (*c*) its significance to economic life. In Volume II of the book major economic activities are studied with the purpose of establishing firmly the relations between these activities and the natural environment of the regions involved.

It should be remembered that economic geography is concerned with man quite as much as with the natural environment, and that man may make and does make a choice as to how his economic life is ordered. It should not be forgotten, however, that Nature sets the broad limits within which man can live and work successfully. Men frequently make unwise choices in economic pursuits, many of which could be avoided with proper knowledge of economic geography. Much knowledge and many desirable practices have been acquired through the ages, not by conscious choice, but by the costly method of trial and error. The Chinese, for example, who very aptly have been called "Farmers of Forty Centuries," have developed a most effective group of practices by which they use the land. In other phases of economic endeavor, however, notably in the utilization of their mineral resources, the Chinese are extremely backward. Knowledge scientifically acquired and organized and applied, in contrast with knowledge hit upon by trial and error, permits elimination of costly mistakes, and expedites wise adjustment of economic life to the natural environment to which it is so vitally related.

The following questions help make clear the scope of economic geography. Appropriate atlas maps should be consulted as the questions are studied. It is not contemplated that these questions will be answered fully or finally at this time. In subsequent exercises most of the points here raised will be studied in detail.

1. So far as you know them, what are the dominant economic activities of the people of Norway, Ceylon, Iowa, the Alps, Southern California, Patagonia, and Western Pennsylvania?
2. Why do the inhabitants of these regions make their living in such different ways?
3. Are all the regions of the earth equally well suited to all economic pursuits? Why?
4. Is every region quite different from all other regions in the particular economic pursuits to which it is suited? Why?

5. In each of the following cases, which area do you think is better suited to the purpose indicated, and why?
   a) Cultivation of the land—Illinois or Nevada.
   b) Production of such crops as rice, rubber, cacao, bananas—England or the Amazon Basin.
   c) A permanent source of timber—Iowa or the Southern Appalachians.
   d) Healthful living for white people—Massachusetts or the Congo Basin.
   e) Wheat raising—the Dakotas or Java.
   f) Supporting a dense population—Tibet or the plains of Eastern China.
   g) An important coal-mining industry—the coal fields of the Ruhr Valley or those of Antarctica.
   h) A slaughtering and meat-packing center—Manaos or Chicago.
   i) A great commercial center—New York City or Sitka, Alaska.
6. Do the inhabitants of all regions make the best possible use of the natural resources of the regions in which they live?
7. What other conditions than those of the natural environment are likely to be of real importance in their influence on the economic life of a region?
8. Which of the following statements is to be preferred, and why?
   a) The economic activities of a region are *determined by* the natural environment of the region.
   b) The economic activities of a region are *influenced by* the natural environment of the region.
   c) The economic possibilities of a region are *closely related to* the natural environment of the region.

CHAPTER II

CLIMATE AND NATURAL VEGETATION

In its bearing on economic life, climate is second to no other element of the natural environment. Like other environmental elements, climate varies greatly from place to place on the earth's surface; probably no place has precisely the same climate as any other place. There are, however, extensive areas throughout which the climate is essentially the same, and it is possible to divide the earth's surface into climatic regions, and to classify the climates of these regions into a comparatively small number of *types*. The types of climate which are distinguished in the following exercises differ markedly one from the other in the kind of economic life that is likely to develop within them. These climates differ particularly in the products that characterize them. Careful study of the exercises will establish (*a*) the characteristics, (*b*) the distribution, and (*c*) the economic life typical of some fifteen major types of lowland climate.

RAINY LOW LATITUDE TYPE OF CLIMATE

1. Are low latitute regions[1] as a whole more or less highly developed economically than middle latitude regions? Why? Than high latitude regions?
2. Name some low latitude products that you know of. Why are most of these articles not produced in the middle latitudes?
3. On a copy of the world-map "Climatic Regions of the Continents," Figure 1 (in the map pocket), color[2] according to the legend the regions having the rainy low latitude type of climate. *Do not color other regions*. When coloring maps, keep your atlas open at the

[1] Low, middle, and high latitudes are terms which correspond in a general way to torrid or tropical, temperate or intermediate, and frigid or polar zones, respectively.

[2] Each student should have a set of good colored pencils, not grease crayons. The following numbers and colors of Blaisdell paper pencils are suitable: 161 red, 157 orange, 154 yellow, 153 green, 150 light blue, 151 dark blue, 147 violet. Color can be applied most evenly if the map is placed on several thicknesses of smooth paper.

appropriate continental relief maps, and constantly make comparisons.

4. Figures 53 and 54 are photographs of places with the rainy low latitude type of climate. Figures 11 and 12 represent the seasonal progression of temperature and rainfall at two places within this type of climate. What seems to be the relation between the facts of climate shown in the graphs and (*a*) the luxuriance of the forest, and (*b*) the fact that there is no marked season of leaf-fall in forests characteristic of this type of climate?
5. In what ways would you suppose natural vegetation of the type shown in Figures 53 and 54 might affect (*a*) agricultural development and (*b*) the building and maintenance of roads and railroads?
6. Read "Classification of Climates" and "The Rainy Low Latitude Type of Climate" (pp. 103–107), and examine Figures 8 (in the map pocket), and 53–59, in preparation for a discussion in class of the bearing of climate on economic life in the rainy low latitude regions.
7. Living conditions in the rainy low latitudes are extremely trying to people from the middle latitudes. Read "Sensible Temperature" and "A Day in the Rainy Low Latitude Type of Climate" (pp. 107–109).
8. On the January and July temperature maps of the world, Figures 2 and 3 (in the map pocket), color, as directed by the legend, the lands with temperatures of 68° F. and above. Why is there so little seasonal and daily range of temperature in the low latitudes? See Figures 60, 66, and 67.
9. On the two half-year rainfall maps of the world, Figures 4 and 5 (in the map pocket), color the lands between the tropics which receive "heavy" and "moderate" rain.
10. Do the facts shown on the four world-maps just colored agree with the representations of the world-map, "Climatic Regions of the Continents," as to the distribution of the rainy low latitude type of climate? Compare the maps carefully for each region shown to have this type of climate.
11. Look up each of the rainy low latitude regions on the appropriate continental relief map in the atlas. What is the general elevation above sea-level of each region? Why do not highlands in the low latitudes have this type of climate?
12. Is there general agreement between Figures 6 and 1 as to the distribution of the type of climate under consideration?

LOW LATITUDE DESERT TYPE OF CLIMATE

1. On the map of "Climatic Regions of the Continents" color the desert regions of the low latitudes. *Do not color other regions.*
2. On the world-maps of half-year rainfall used in the preceding exercise, note the areas receiving 10 inches or less, up to about latitudes 35° N. and 35° S. Also consult annual rainfall map in your atlas.
3. On the temperature maps for January and July, color the lands having average temperatures between 50° and 68° F.
4. Would you expect the average density of population in the low latitude deserts to be high or low? Why?
5. Do the facts shown on the world-map of density of population, Figure 8 (in the map pocket), check with your answer to the preceding question? On this population map color the continents, as directed by the legend, between latitudes 35° N. and 35° S.
6. Where within low latitude desert regions do you suppose most of the people live? Why?
7. Do transitions in rainfall, temperature, vegetation, and population density coincide approximately with the boundaries of the low latitude deserts as represented on the map of "Climatic Regions of the Continents"?
8. Read "The Low Latitude Desert Type of Climate" and "Windstorms in a Low Latitude Desert" (pp. 109–113), and examine Figures 16 and 69–71 in preparation for class discussion of the relationships of plant, animal, and human life to climate in low latitude deserts.
9. Read "The Coastal Desert of Northern Chile" (p. 113). In what respects is the climate of this desert typical of all low latitude deserts, and how is it distinctive?
10. Precise knowledge of the location of places is as fundamental to geography as the multiplication table is to arithmetic. To learn by rote long lists of place-names is futile, but to look up on a map and fix in mind the location of plains, mountain ranges, rivers, seas, cities, and other features involved in any geographic study is imperative. It is urged that each student keep a list of place-names occurring in each day's assignment, the location of which seems to be worth remembering. The list will receive additions daily, and from time to time it should be reviewed carefully with an atlas in hand. Places not in your atlas should be looked up in a larger atlas in the library.

WET-AND-DRY LOW LATITUDE AND SEMI-ARID LOW LATITUDE TYPES OF CLIMATE

1. How would you expect natural vegetation in the regions with a distinct season of rain and a distinct season of drouth to differ from that in the regions with rain all year, and from that in regions which are dry all year? Why? See Figures 53, 54, 59, and 69–75.
2. Examine the graphs of low latitude climates (Figs. 11–16), and determine (*a*) which represent climates that are rainy all year, (*b*) which those that are dry all year, and (*c*) which those with alternate seasons of rain and drouth.
3. Rhythm of rain and drouth results in a corresponding rhythm in agricultural operations in many low latitude regions. Why should this be the case?
4. Examine again the graphs of stations with alternating rain and drouth (Figs. 13–15). Note that the length of the rainy season differs. How might these differences affect agriculture?
5. On the world-map of "Climatic Regions of the Continents," locate the stations referred to in the preceding question. What distinction is made on this map as to the climate of these places? Read "The Wet-and-dry Low Latitude Type of Climate," "The Semi-arid Low Latitude Type of Climate," "Agricultural Practices in India," and "Weather Conditions in the Zambezi Basin" (pp. 114–121), noting carefully differences in climatic characteristics and in economic life of the regions where the two climates prevail. In this connection study Figures 76–87.
6. On the world-map of "Climatic Regions of the Continents," color the regions which have the wet-and-dry low latitude climate; then color the regions having the semi-arid low latitude type. What system can you trace in the distribution of the four low latitude types of climate?
7. On the half-year rainfall maps color the low latitude areas having "light" precipitation. Do the facts on these maps tally with rainfall conditions as you understand them in the two types of climate under discussion?
8. From the standpoint of economic possibilities, what is the great difference between, on the one hand, the rainy and the wet-and-dry low latitude types of climate, and, on the other, the desert and the semi-arid types?
9. Does the world-map of natural vegetation (Fig. 6) reflect the climatic differences brought out in this exercise? Do the con-

trasts in natural vegetation seem to result chiefly from differences in temperature or in rainfall?

10. How would you expect the following types of low latitude climate to differ in comfort and in healthfulness for people from the middle latitudes: (*a*) the rainy, (*b*) the wetter phase of the wet-and-dry, (*c*) the drier phase of the wet-and-dry, (*d*) the semi-arid, and (*e*) the desert? Do the world-maps of January and July temperatures shed any light on this question? What other conditions are involved?
11. Compare the temperature maps with the half-year rainfall maps. What additional climatic elements affecting human comfort are suggested by the rainfall maps?
12. Exceptionally destructive storms occur at certain seasons in some regions possessing the rainier phase of the wet-and-dry low latitude type of climate. Read "Tropical Cyclones, Typhoons, and Hurricanes" (pp. 121–125), and see Figure 88.
13. Indicate on the world-map, "Climatic Regions of the Continents," all stations in this and the preceding exercises for which climatic graphs are given. In subsequent exercises add the stations for which graphs are given.

CLIMATES OF HIGHER ALTITUDES IN THE LOW LATITUDES

1. Consult the largest scale atlas map showing Mexico City and Vera Cruz. In which city would you prefer to live? Why?
2. Have facts shown on the world-maps of January and July temperatures any bearing on the preference you have just expressed?
3. On the maps of population and relief, note the highlands of Colombia, Ecuador, Peru, and Bolivia. How do they compare in density of population with the lowlands to the eastward? These countries have been developed mainly by Spaniards. The Spaniards found a highly developed native civilization in the highlands. Why do you suppose more progress has been made on the highlands than on the lowlands to the east? Than in the lowlands to the west?
4. Note that the population is in general denser on the highlands of Costa Rica, Nicaragua, Honduras, Salvador, and Guatemala than on the lowlands. Do you suppose the reasons for this are similar to those that apply in the case of the South American countries listed in the preceding question?
5. Read "High Altitude Climates in the Low Latitudes" (pp. 125–131), and examine Figures 88, 90–97, and 41–45.
6. How does the character of economic life in the highland sections of the Central and South American countries referred to in Questions 3 and 4 differ from its organization on adjacent lowlands?
7. What are the major contrasts in economic pursuits between the highlands of Central America, Mexico, Colombia, Ecuador, and Peru? Between these groups of highlands and the Bolivian Plateau?
8. The daily range of temperature on highlands is greater than on nearby lowlands. Of what significance is this fact? Compare Figures 61 and 60.
9. Figure 96 shows one of the so-called "hill stations" of India. Compare its location, as shown on an atlas map, with that of Calcutta. Which season would you expect the Europeans of Calcutta to spend at Darjeeeling and other Indian hill stations? From the standpoint of Europeans, what are the significant differences in climate between Darjeeling and Calcutta, as brought out by the table on page 131 and by Figures 13 and 42? Compare Figures 96 and 95.

10. On appropriate atlas maps of the largest scale available, look up the following highlands in which there are mountain resorts which play an important rôle in enabling European business men, political officials, and missionaries to carry on their work on the nearby lowlands: the Nilgiris, the Himalayas, and the upland cores of Ceylon, Sumatra, Java, Jamaica, Porto Rico, and the Philippines.
11. Compare the world-maps of relief, January and July temperatures, and half-year rainfall, with that of "Climatic Regions of the Continents." On the last-named map color violet the highlands which you believe belong to the low latitudes.

REVIEW OF LOW LATITUDE TYPES OF CLIMATE

1. Is the density of population about the same in all regions with a given type of climate? Why? In regions with different types of climate? Why?
2. For each of the following low latitude lowland regions, determine from appropriate maps and put into a well-arranged table to be handed in,[1] (*a*) type of climate, (*b*) average temperature for January, (*c*) average temperature for July, (*d*) average rainfall from November 1 to April 30, (*e*) average rainfall from May 1 to October 31, (*f*) character of the natural vegetation, (*g*) approximate elevation, and (*h*) density of population: Panama, East Coast of Central America, Pacific Coast of Columbia, the Amazon Basin, the Guinea Coast and inner Congo Basin, the East Indies and Malay Peninsula between 5° S. Lat. and 10° N. Lat., Southeast Coast Brazil to about 24° S. Lat., East Coast Madagascar, East Coast Indo-China, borders of the Gulf of California, West Coast South America south of Guayaquil, the Sahara, Somaliland, Arabia, the Thar, the Kalahari, Central Australia, West Coast of Mexico and Central America, the West Indies, the Llanos, the Campos, the Southern Sudan, the Southern Congo Basin, East Coast Africa between latitudes 10° and 24° S., the Deccan, the Ganges Plain, Burma, Siam and Western Indo-China, South Coast China, extreme Northern Australia and nearby East Indies, Ceará, the Northern Sudan, inland East Africa, the Zambezi Basin, Mesopotamia, inland Northern Australia.
3. For each of the following points and each of the lowland low latitude types of climate, write and hand in[1] a complete but brief series of statements concerning the bearing of climate on (*a*) characteristics of the natural vegetation, (*b*) wild animal life, (*c*) human health, energy, and comfort, (*d*) agriculture, (*e*) production of commodities other than agricultural, (*f*) trade and trade routes, and (*g*) type of civilization. The following statement, covering the natural vegetation in the rainy low latitude climate, is an example of the sort called for: "Year-round or practically year-round high temperature and plentiful rainfall make the growing season continuous in the rainy low latitudes, and result in luxuriant forests of large, broad-leaved trees which have no well-defined season of leaf-fall."

[1] These written assignments may well take two or three days to finish.

4. Read "Climate and Civilization in the Low Latitudes" (p. 132).
5. Climatic data for a number of stations other than those shown in the graphs are given on pages 190–191 and should be consulted from time to time as climate is studied. So far as you can, indicate which of the stations in the table represent one or other of the low latitude climates?

MIDDLE LATITUDE CLIMATES

1. What are the chief similarities and what are the outstanding differences between the economic activities of the people of middle latitude regions and of those of low latitude regions? In what ways do differences in climate seem to be responsible for the differences in economic life?
2. On the world-maps of seasonal rainfall and temperature which you have used in previous exercises, color the lands up to about latitudes 60° N. and 60° S. How do the middle latitudes differ from the low latitudes in temperature? In rainfall?
3. Compare the climatic graphs of middle latitude stations with those of low latitude stations (Figs. 11–37 and 60–65). Do they bring out the same differences as do the maps?
4. What are the major consequences of the marked seasonal rhythm in temperature in the middle latitudes (*a*) to agriculture and (*b*) to human health and energy?
5. The chief reasons for a well-defined seasonal rhythm in temperature in the middle latitudes are marked differences from season to season (*a*) in the length of day and night, and (*b*) in the angle at which the sun's rays strike the earth's surface. Figures 66–68 help to explain these points.
6. In your judgment are the differences in temperature from place to place within the middle latitudes more or less significant to human life and activities than the differences in rainfall? Consult the world-maps of temperature, rainfall, natural vegetation, density of population, and wheat (Fig. 98).
7. Can types of climate in the middle latitudes be differentiated most satisfactorily on the basis of temperature, rainfall, or both?

CLIMATE OF WEST MARGINS OF CONTINENTS IN LOWER MIDDLE LATITUDES, OR DRY SUBTROPICAL TYPE OF CLIMATE

1. What similarities in the climate of Southern California, Central Chile, and the Mediterranean region appear from a comparison of the temperature and rainfall maps, and Figures 17–20?
2. On a fresh copy of the world-map of "Climates of the Continents," color the regions which have the dry subtropical climate. Do these regions lie on the east or the west sides of the great continental masses? Are they in the equatorial or the poleward portions of the middle latitudes? What locational name is sometimes applied to this type of climate?
3. What do the temperature maps, and the temperature graphs in Figures 17–37 indicate as to the severity of the winters in the dry subtropical regions as compared with most other middle latitude regions? What explanation for the difference can you offer?
4. In view of the mild winter temperatures and the seasonal concentration of rainfall in the dry subtropical climate, does it seem as though wheat and barley, which are the chief grains grown in this climate, would be planted in autumn and harvested in early summer, or planted in spring and harvested in late summer or early autumn? Check your conclusion with the maps of the wheat-growing areas in Europe (Figs. 103 and 104).
5. Figures 109 and 110 show a characteristic perennial agricultural plant of this climate that ordinarily is not irrigated. How this plant solves the problem of living through the dry summer is suggested in the discussion of the dry subtropical climate (pp. 132–135).
6. Dried fruits, such as raisins, currants, prunes, peaches, and apricots, are characteristic products of this type of climate. How does the climate favor this industry?
7. What probably is the best-known product of Southern California that reaches the markets of the Eastern United States? This product is likewise important in other regions having the same type of climate. Figure 111 shows a grove of the trees. Why should irrigation be practiced in these groves and not in the wheat and barley fields of the same regions?
8. Killing frosts are rare in the dry subtropical climate, but their occasional occurrence is likely to cause great losses. Why?

Read "Saving the Crops from Injury by Frost," and "Weather Bureau Fruit-frost Service in Southern California" (pp. 135–141), and see Figure 112.

9. In all regions having this climate, grazing is an important industry. Why is this natural? What are the chief animals raised? Why?
10. Make a list of the agricultural practices which are characteristic of the dry subtropical climate.
11. When Solomon was building the Temple at Jerusalem he made a contract with the king of Tyre to supply the necessary timber, which was obtained from the Lebanon Mountains. Examine a detailed map of the lands at the eastern end of the Mediterranean, and determine the bearing of climate on this transaction.
12. Southern California, Italy, the French Riveria, and the Crimea are celebrated winter resorts, chiefly because the climate of these regions differs from that of the homeland of the tourists. What are the differences?
13. From the standpoint of comfort, what are the most trying features of the dry subtropical climate? Read "Annoying Winds of the Dry Subtropical Climate" (pp. 141–142).
14. The Mediterranean Sea has been called the "cradle of navigation." Until modern times, however, navigation was largely limited to the summer season. What were the advantages of that season as compared with the winter?
15. In most of the regions with this type of climate, winds are very weak most of the time in the summer; in the winter they are stronger, but are variable in direction. Rain presumably falls when the winds blow from the sea or the land? Would you expect continuous rain in the winter, or "spells" of rain and spells of clear and sunny days? Why does most of the rain come in the cooler half of the year? In this connection consider (*a*) the relative strength of summer and winter winds, and (*b*) land temperatures as compared with sea temperatures in summer and in winter?

CLIMATE OF EAST MARGINS OF CONTINENTS IN LOWER MIDDLE LATITUDES, OR HUMID SUBTROPICAL TYPE OF CLIMATE

1. South Carolina differs markedly from Southern California in its agriculture, although it lies in about the same latitudes. Cotton and rice, rather than oranges, dried fruits, olives, and wheat are characteristic crops. From your general knowledge of these two areas, do you suppose that differences in climate are in any important way responsible for differences in agriculture?
2. Check your tentative conclusions by examining (*a*) seasonal temperatures and (*b*) amount and seasonal distribution of rainfall of these areas, as shown on the world-maps, and in the graphs (Figs. 17–24). Read the discussion of the humid subtropical climate (pp. 142–145), and see Figures 98–102, 108, 109–121.
3. With the thermometer registering 90° F. in Southern California and in South Carolina, which feels hotter? Why? Re-read "Sensible Temperature" (p. 107). Note that in midsummer, temperature, rainfall, and relative humidity at certain seasons in the humid subtropical climate approximate conditions in rainy low latitude regions. Compare Figures 62 with 60 and 22 with 11.
4. The following statement is quoted from a pamphlet issued by the Atlanta Convention Bureau: "Atlanta, the City with an Ideal Year-Round Climate. Weather is like that of the famous Swiss Resorts. Only one degree difference between mean temperature in Atlanta and in Los Angeles. . . . . One reason for this is that we are a pinnacle city . . . . 1,050 feet above sea level." Examine the table, "Average Temperatures for Atlanta, Los Angeles, and Geneva" (p. 145). Is the mean annual temperature of a place a fact of much geographic significance? Why?
5. On the copy of the world-map of "Climates of the Continents" used for the dry subtropical climate, color the regions indicated as having the humid subtropical climate.
6. Study the half-year rainfall maps and the graphs (Figs. 21–24) to determine the outstanding differences in climate between the several regions just colored. Does it seem permissible to designate as of the same type, climates that differ as much as do those of the regions just colored? What test of economic geography may be applied to determine whether or not the climates of several regions are nearly enough alike to be included in one type?

7. In some regions it is customary to cure the grain by methods similar to those shown in Figures 116–118. Why?
8. The Gulf Coast of the United States and the borders of the China Sea are subject, at certain seasons, to peculiarly destructive storms (see Fig. 89), of which the Galveston hurricane of September, 1900, is a historic example. After the 1900 hurricane a high seawall was built at Galveston to protect the city from a recurrence of the accompanying tidal wave which caused most of the damage. Why are tidal waves a common accompaniment of tropical hurricanes and typhoons?
9. In Texas, Argentina, and Southeastern Australia, the western part of the regions mapped as having this type of climate (Fig. 1) have so much less rainfall than the eastern parts of these regions that their agriculture is markedly different. These less rainy regions should be thought of as having the drier phase of the climate of east margins of continents in lower middle latitudes. See Figures 98 and 195*b*.

CLIMATE OF WEST MARGINS OF CONTINENTS IN HIGHER MIDDLE LATITUDES, OR MILD-WINTER–MILD-SUMMER CLIMATE

1. How would you describe the temperature conditions of the places represented in Figures 25, 26, and 65? Within what latitudes do these places lie? Are they on the east or the west sides of the continents? How far are they from the sea?
2. On the copy of the world-map of "Climatic Regions of the Continents" used for other middle latitude types, color the regions having the mild-winter–mild-summer climate of the west sides of continents in the higher middle latitudes.
3. Using the rainfall and temperature maps, and the graphs in Figures 17–26, pick out similarities and differences between this type of climate and those of the *lower* middle latitudes, (*a*) on the west margins, and (*b*) on the east margins of the continents.
4. Consult pages 146–147 and Figures 122–124 for details of the relation between (*a*) abundant rainfall, fine forests, and the timber business, (*b*) rainfall, winter and summer temperatures, luxuriant pasturage, and dairying, and (*c*) climate and crops, in the regions having this type of climate.
5. To what extent does it seem likely that climate is responsible for the growth of large and varied manufacturing industries in Northwestern Europe, and for the lack of such development in Southern Chile, the Puget Sound Region, and Tasmania and New Zealand?
6. In the regions named in the preceding question, winds are variable in direction at all seasons. In general they are stronger in the cooler half of the year. Probably most of the rain is brought by winds from the land or the sea? Why? Why is the cooler half of the year rainier than the warmer half?
7. Can you account for the fact that this type of climate extends less far inland in the Puget Sound Region than in Western Europe? What do the rainfall maps suggest as to the source of moisture received by the Western European region?
8. Figure 65 shows strikingly the absence of a *hot* summer and a *cold* winter in this type of climate. How are these conditions reflected in the following aspects of British life: general dependence on open fires rather than on furnaces or steam plants, customary use of clothing of about the same weight throughout the year, and a continuous season of outdoor sports. Football is played from September to March, and indoor games, such as basket-ball, are scarcely known.

HUMID CONTINENTAL CLIMATES WITH LONG SUMMERS AND WITH SHORT SUMMERS

1. On the copy of the world-map of climatic regions last used, color (*a*) the regions having the humid continental type of climate with long summers, and (*b*) those having the humid continental climate with short summers. Read "Introduction to the Continental Types of Climate" (p. 147).
2. Which of the regions just colored raise spring-sown wheat, and which autumn-sown? See Figures 98, 103–107, 125.
3. Which of these regions raise much corn, and which little or none? See Figures 100 and 126.
4. Are rice and cotton important crops in these two types of climate? See Figure 99.
5. Note that although wheat is a major crop in the two continental climates (Fig. 98) it apparently does not thrive in most regions with the humid subtropical climate.
6. The relations between climate and the agricultural facts noted in the preceding questions are set forth in the discussion of the two humid continental types of climate (pp. 147–151). Consult also Figures 27–33, 2–5, 108, 127, and 128.
7. "Hard wheat," which is relatively high in gluten content, characterizes the drier wheat regions of the world, and "soft wheat," which is relatively high in starch content, the less dry wheat regions. Which type of wheat do you suppose is grown in North Dakota, Kansas, Illinois, Hungary, Southwest Siberia, North China?
8. In North China and Southern Manchuria "kaoliang," a grain sorghum, is a leading crop (Fig. 128). This crop withstands the drouths of this region better than corn. Into what other areas having the humid continental type of climate might kaoliang be introduced as a substitute for corn?
9. What is the bearing of climate on each of the following conditions in the United States?
   a) The trade in early fruits and vegetables between the South and the North. See Figures 127, 129 and 130.
   b) The migration of large numbers of southern people to northern summer resorts.
   c) The development of many winter resorts in the South. See Figures 62–64.
   d) The fact that negro slavery became established in the South while it died out in the North.

e) The fact that in the North the broad-leaved trees are deciduous, whereas in the South many of them are evergreen, as for example, the live oaks and the magnolias. See Figures 127, 131 and 132.

f) The absence in the South of the industry shown in Figure 134.

10. From the world-map of natural vegetation (Fig. 6), discover what sorts of vegetation are native to the humid subtropical and the two humid continental types of climate.

11. How do natural forest and natural grassland correspond to the amount of precipitation in these types of climate? See half-year rainfall maps.

12. Within the sections of the two humid continental types of climate originally forested, how do deciduous, or broad-leaved forest and coniferous forest correspond to the differences in temperature? See January and July temperature maps.

13. Chicago weather is likely to be as penetratingly cold as Minneapolis weather, even when the thermometer at Chicago does not register so low as at Minneapolis. Explain how this can be.

14. Occasional blizzards, with heavy snowfall, are characteristic of some areas of humid continental climate. Read "A Middle West Blizzard" and "Winter Operation of Railroads in the Northern Part of the Lower Peninsula of Michigan" (pp. 152–154). See Figures 131 and 133. Much of the summer precipitation in these types of climate falls in thunder-showers. Read "Types of Thunderstorms" (pp. 154–155).

15. Tornadoes (which should be distinguished from tropical cyclones, hurricanes, or typhoons) occasionally do much damage in restricted areas within middle latitude continental interiors. Most tornadoes occur during the late spring and early summer months in regions with the long summer type of humid continental climate.[1] Read "Tornadoes" (pp. 155–159), and see Figures 135 and 136.

16. An important economic consequence of seasonal variation in length of daylight is suggested by Figure 137. What other consequences grow out of this seasonal variation in the length of daylight? Is such variation confined to the humid continental types of climate? How and why does the seasonal variation in length of daylight vary in different parts of the earth? See Figures 66–67.

[1] For a detailed study of a place having the humid continental climate see L. F. Thomas, *The Climate of Saint Louis, Missouri. Washington University Studies*, XII (1924), pp. 1–29.

CLIMATE OF EAST MARGINS OF CONTINENTS IN HIGHER MIDDLE LATITUDES, OR MODIFIED HUMID CONTINENTAL TYPE

1. On the copy of the world-map of climatic regions last used, color the regions having the climate of the east margins of the continents in the higher middle latitudes.
2. What differences between this climate and the humid continental types are indicated by the rainfall and temperature maps, Figures 27–34, and 138, and the table "Comparative Climatic Data for Winnipeg, Omaha, Columbus, and Portland" (p. 159)?
3. Ascertain from the maps of corn, spring-sown wheat, fall-sown wheat, and potatoes (Figs. 100, 98, 105, 106, 107, 101) which of these crops are typical of the modified continental climate. How and why do the crops of this climate differ from those of the two humid continental types? Read the discussion of the modified continental climate (pp. 159–160).
4. The climatic differences referred to in Question 2 are due mainly to the influence of the nearby ocean. After reading "The Continental and the Marine Influence in Climate" (p. 161), explain the differences you have noted.
5. Boston seems about as hot as Omaha in midsummer, although most of the time the thermometer does not register so high. Why is this the case?
6. Contrast the climates of Portland, Maine, and Portland, Oregon, after studying the table "Climatic Data for Portland, Maine, and Portland, Oregon" (p. 162).
7. Do the following figures conceal or reveal the significant temperature differences between the places which they represent? How?

City	Average Annual Temperature
Peoria, Illinois	50° F.
Winnipeg, Manitoba	34° F.
St. John, New Brunswick	39° F.
Portland, Oregon	53° F.
Portland, Maine	45° F.

MIDDLE LATITUDE DESERT CLIMATE

1. What is a desert? See Figure 139.
2. Consult world-maps of rainfall and natural vegetation, and locate all desert regions other than those in the low latitudes, already studied.
3. On the copy of the world-map of climatic regions last used, color the middle latitude deserts.
4. Is the climate of middle latitude deserts in any way markedly different from that of low latitude deserts? Use the rainfall and temperature maps, and the graphs in Figures 16, 35, and 36 to prove your point.
5. Of what economic significance is the climatic fact established in your answer to the preceding question? Read "The Middle Latitude Desert Type of Climate" (pp. 162–163).
6. Where is most of the population in middle latitude deserts? Is this distribution similar to that in low latitude deserts? See world-map of density of population and Figures 142 and 149.
7. How does the density and distribution of population in the arid regions of Western United States differ from that in the humid East, as suggested by Figure 141? Why? Do you suppose this contrast between arid and humid regions in the middle latitudes is typical? Do you think it is permanent?
8. Are most desert regions on the seacoast or inland? Why does this seem natural? Why are regions cut off from the sea by mountain ranges likely to be deserts? See Figure 140. Suggest plausible causes for seacoast deserts.

SEMI-ARID MIDDLE LATITUDE CLIMATE

1. Between what sorts of climate do the areas with the semi-arid middle latitude type lie, as shown by the world-map of climatic regions? Color these semi-arid regions on the copy of this map used for middle latitude deserts.
2. Note the more striking ways in which man in these semi-arid regions has adapted his economic life to climate, as described in "The Semi-arid Middle Latitude Climate" (pp. 163–164). See Figures 140–145, 4–6 and 37.
3. Ordinarily the amount of water applied to irrigated fields in middle latitude semi-arid regions, is less than that applied in middle latitude deserts. Why?
4. Most regions in the dry subtropical type of climate have about the same annual rainfall as semi-arid middle latitude regions, but they are not commonly classed as semi-arid. Why? Refer to the graphs in Figures 17–20, and 37, noting the seasonal distribution of rainfall.
5. Amarillo, Texas, and Moosejaw, Saskatchewan, receive about the same annual precipitation, with about the same seasonal distribution; yet the former is in grazing country, whereas the latter is in wheat country. The explanation of this apparent inconsistency is to be found in the rate of evaporation, which is much lower at Moosejaw. Consult the world-maps of temperature. Why may evaporation be the critical factor which makes crop-raising possible in one region but not in another?
6. What practices are employed in dry-farming to reduce evaporation? Read "Dry-Farming in Semi-arid Regions" (pp. 164–166). Do all dry-farming practices aim at reducing evaporation?
7. In the United States the one hundredth meridian sometimes is taken as the boundary between the East and the West. What justification is there for this?
8. In what ways does the life of nomads in semi-arid regions differ from that of sedentary dwellers in humid middle lattiudes? Read "Life of the Nomadic Khirghiz" (pp. 166–167), and see Figure 146.
9. Look up the location of the "Great Wall of China" on an atlas map and see Figure 147. The Great Wall was built many centuries ago by the agricultural Chinese to keep out the raiding

Mongols. What is the significance of the close coincidence between the course of the wall and the line between different types of climate?

10. Figure 148 illustrates the common means of transportation for many, many centuries in the trade between China and Mongolia. Why do you suppose camels rather than horses were employed? What commodities do you suppose were traded?

THE VARIABLE WEATHER OF THE MIDDLE LATITUDES—FIRST EXERCISE

1. One of the noticeable features of the climate of most middle latitude regions is the variability of the weather within periods of a few days' length. Compile a list of all the ways you can think of in which these "spells" of weather have a bearing on human activities in the regions concerned. Read "The Significance of Variable Weather in the Middle Latitude Types of Climate" (p. 168).
2. Why is it useful to be able to predict the weather a day or more in advance?
3. In order to predict the weather most successfully, it is necessary to know something of the causes of weather. The questions which follow, *if studied carefully in sequence*, will introduce the student to weather prediction, and will enable him to understand better than he otherwise could, the influence of weather on man's activities. It should be kept in mind that these questions refer to regions in the Northern Hemisphere. Conditions in the middle latitudes in the Southern Hemisphere are similar, but not exactly the same.
4. In the middle latitudes are most cold and cool winds northerly or southerly (winds are named according to the directions from which they blow)? Why? From what general direction do the hot and warm winds blow?
5. A change of winds from northerly to southerly is likely to have what effect on temperature? Why? A change from southerly to northerly?
6. Are southerly winds generally moving into cooler or warmer areas? As a result, is the air thus moving being cooled or warmed? What is the case with northerly winds?
7. The moisture-holding capacity of air decreases as it is cooled and increases as it is warmed. Air that contains all the moisture it can hold is said to be saturated. In most cases saturation of air is accomplished by cooling. The relative humidity of air at the point of saturation (i.e., the amount of moisture it holds in proportion to the amount it can hold), expressed in percentage, is 100.
8. As a rule is the relative humidity of the air in northerly winds increasing or decreasing? Why? Of southerly winds? In

which case, therefore, is saturation of the air more likely to be brought about?

9. Clouds are composed of droplets of water floating in the upper air. These droplets are formed by condensation of the moisture in the air; such condensation begins to take place only when the air reaches the point of saturation.

10. Are clouds more likely to be formed, by saturation of the air, in northerly or in southerly winds? Why?

11. Precipitation takes place from clouds. From the reasoning of the preceding questions, does it seem as though northerly or southerly winds are more likely to be accompanied by rain? Why?

12. Weather in the middle latitudes can be more satisfactorily predicted with a "weather map" than without such a map. Weather maps, of which Figure 156 is an example, are prepared by plotting observations of weather elements—temperature, precipitation, cloudiness, direction and velocity of wind, and atmospheric pressure—taken simultaneously at various stations within the area mapped. Each map thus represents weather conditions at a given moment of time. Temperatures are shown on the map by means of "isotherms," which are lines connecting points of equal temperature; in Figure 156 isotherms are dotted lines. Precipitation may be indicated by symbols in circles—"R" for raining and "S" for snowing. Cloudiness likewise is shown by means of circles; a black circle indicates a cloudy sky (more than .7 overcast), a half-black circle represents a partly cloudy sky (between .3 and .7 overcast), an open circle a clear sky (less than .3 overcast). Wind directions are shown by arrows which fly with the wind.[1] Atmospheric pressure is represented by means of "isobars," lines connecting points of equal pressure; in Figure 156 isobars are solid lines. In addition to these items, which portray conditions for the moment of observation, areas which have received precipitation during the twenty-four hours preceding the moment of observation are shaded. Study carefully the symbols on the current weather map which is posted.

13. By plotting air pressures (read from the barometer) on a map, it is found that there are large areas within which pressures are relatively low, and other areas within which pressures are relatively high. These areas are indicated on weather maps by printing

[1] Bear in mind that the arrow on a weather vane *points into the wind*, but that a wind is given the name of the direction from which it blows.

the words LOW and HIGH on their central portions. Pressures are greater near the center of a HIGH than in the outward portions; the reverse is true in a LOW. What are the approximate diameters of the HIGHS and LOWS mapped in Figure 156? The boundary between a HIGH and an adjacent LOW is of course not sharp; one grades into the other.

14. As a result of pressure differences within a LOW, air moves (in other words winds blow) into the center; in the case of a HIGH, winds blow out from the center. Unless some local condition causes an unusual state of affairs, wind arrows cut the isobars obliquely to the right of a 90° angle. See Figure 151. The horizontal movements just described are accompanied by rising air in the central portion of a LOW, and by descending air in the central portion of a HIGH. See Figure 152.
15. On the diagrammatic weather map (Fig. 153), "wind-shift lines" have been drawn through the centers of the HIGH and the LOW, so as to separate the areas with southerly winds from those with northerly winds. Are the winds to the west of the wind-shift line of the LOW, and to the east of the wind-shift line of the HIGH, southerly or northerly? As a result of these winds, are the temperatures of places between these wind-shift lines probably rising or falling? Why? Is the weather probably clear or cloudy in the area under consideration? Why? Is there a likelihood of rain in the area? Why?
16. In similar fashion describe and explain conditions to the east of the wind-shift line of the LOW and west of the wind-shift line of the HIGH.
17. Air expands as it rises, because of the lower pressures at higher altitudes. Why should there be lower pressures in higher altitudes? Expanding air cools. Should cloudy or clear weather therefore be expected aloft in the central portion of a LOW? Why? Is precipitation likely or unlikely? Why?
18. Descending air is compressed, because of the greater pressures at lower altitudes. Why should pressures be greater in lower altitudes? Through compression air becomes warmer. Should cloudy or clear weather therefore be expected in the central portion of a HIGH? Why?
19. Suppose the pressure areas on the diagrammatic weather map (Fig. 153) moved with their centers following the path indicated. A place north of this path might occupy successively the positions

represented by the black dots numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. What succession of winds would this place have, and why? What changes of temperature, and why? What probable changes in sky conditions and precipitation? Why? A place south of the path might occupy successively the positions lettered *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*. What succession of weather conditions would this place have?

20. Within what period of time are such successions of wind likely to occur? See table, "Hourly Wind Record at University of Chicago Observatory" (p. 169).

THE VARIABLE WEATHER OF THE MIDDLE LATITUDES—SECOND EXERCISE

1. Which of your customary activities are affected by variations in the weather? Read "Some Consequences of Weather" (pp. 170–171).
2. Most places in the middle latitudes have almost constantly changing weather. In fact, about the only constant feature of typical middle latitude weather is frequent change. See Figure 155. This is a result of the fact that low pressure and high pressure areas of the sort represented on the weather map, Figure 156, move along paths similar to those shown in Figure 154. In the middle latitudes of both hemispheres HIGHS and LOWS move from west to east in endless succession, over continents and oceans. Just why does variability of weather result from this movement of HIGHS AND LOWS?
3. HIGHS and LOWS in most regions move more rapidly and are more strongly developed in winter than in summer. From this does it seem as though weather changes should be more frequent and more marked in winter or in summer? Why? See Figures 62–65. Does your conclusion tally with your experience?
4. The weather maps of March 29, 30, 31, 1923 (Figs. 156–158), show the progress of a cold wave in central Illinois. Explain the relation between changes in pressure, wind, and temperature at Springfield, Illinois. What probably were some of the consequences of this succession of weather conditions to the people of Springfield?
5. On an outline weather map[1] plot and date the successive positions of the isotherm of 30° F. east of the ninety-fifth meridian as shown on the maps, Figures 160–162. What caused this movement of the isotherm? What was the significance of this movement of the isotherm to the fruit and early vegetable industry of Florida? Read "The Florida Freeze of 1894" (pp. 172–173).
6. In each of the following cases in southwestern Michigan, which vineyards are more liable to be frosted in a September cold snap? Why?
   a) Those near the tops of hill slopes, or those in depressions at the bottoms of hill slopes.

[1] Outline weather maps for use in such exercises can be obtained from "Chief U.S. Weather Bureau," Washington, D.C. Order "Station base maps" at 25 cents per hundred.

b) Those on dark- or those on light-colored soil.

c) Those on sandy or those on clay soils.

d) Those in an area covered with clouds, or those in a clear area.

e) Those where a wind is blowing, or those where the air is still.

Re-read "Saving the Crops from Injury by Frost" (pp. 135–139).

7. Prolonged heat and deficient rainfall did much damage to the corn crop of Kansas in the summer of 1916. The map, Figure 159, shows these undesirable weather conditions, which are discussed in "The Hot, Dry Summer of 1916 in Kansas" (pp. 171–172).

THE VARIABLE WEATHER OF THE MIDDLE LATITUDES —THIRD EXERCISE

1. What use could you make of the ability to predict the weather of the following day?
2. *a*) Enter on an outline weather map the figures for the rainfall for the twenty-four hours ending 8:00 A.M., Eastern Standard Time, October 10, 1919, for the following stations. These figures were taken from the table published with the daily weather map. The figure for each station should be printed in place on the outline map.

Station	Inches	Station	Inches
Albany, New York	.1	Louisville, Kentucky	.2
Alpena, Michigan	.2	Ludington, Michigan	.1
Boston, Massachusetts	.2	Minnedosa, Manitoba	.1
Buffalo, New York	.1	Montreal, Quebec	.5
Cairo, Illinois	.1	Northfield, Vermont	.1
Chicago, Illinois	1.3	Pittsburgh, Pennsylvania	.6
Cincinnati, Ohio	.4	Port Arthur, Ontario	.1
Cleveland, Ohio	.1	Quebec, Quebec	.4
Columbus, Ohio	.3	Saginaw, Michigan	.1
Davenport, Iowa	.4	Saugeen, Ontario	.4
Detroit, Michigan	.8	S.St. Marie, Michigan	.8
Dubuque, Iowa	.1	Scranton, Pennsylvania	.2
Eastport, Maine	.3	Syracuse, New York	.2
Erie, Pennsylvania	.1	Toledo, Ohio	.4
Escanaba, Michigan	.4	Toronto, Ontario	.4
Evansville, Indiana	.2	Wausau, Wisconsin	.3
Grand Rapids, Michigan	.1	Winnipeg, Manitoba	.2
Green Bay, Wisconsin	.1		

b) Enter on the same outline map the successive positions of the wind-shift line of the LOW centering over Minnesota on October 9, and over Michigan on October 10, 1919 (Figs. 163–164).

c) Where probably was the wind-shift line when most of the rain fell that you have plotted on the outline weather map? Why?

d) Where probably was the wind-shift line when the rain fell at the stations in Wisconsin and Northern Illinois? Why?

e) The weather forecast for Chicago issued October 10 was as follows: "Fair and much colder tonight, probably with heavy frost; Saturday, fair and continued cold; moderate to fresh

northwest winds diminishing tonight." How does the map justify such a forecast?

3. Consult the daily weather maps on display,[1] and work out the probable weather for the next day without looking at the official prediction. Then compare your prediction with the official forecast.
4. What effect on the success or failure of weather predictions might each of the following conditions have?
   a) A slowing-down or a speeding-up of the rate at which a LOW or a HIGH is moving.
   b) An increase or a decrease in the intensity of an advancing HIGH or LOW.
   c) A change in direction of movement of an advancing HIGH or LOW.
   d) The unexpected appearance or disappearance of a HIGH or LOW? All of these, as well as other disturbing conditions, actually occur. Nevertheless, such disturbing conditions are the exception rather than the rule, and 84% of predictions made by the United States Weather Bureau come true.[2]
5. Each day hereafter, whenever practicable, predict the weather from the map, and then compare your forecast with (*a*) the official forecast and (*b*) the actual weather of the next day. Wind-shift lines are not printed on the official weather maps, but their position and movement should be determined, for such knowledge helps greatly in predicting the weather.
6. The habit of observing *out-of-doors* changes in the weather from day to day should be cultivated. One learns presently that certain conditions are likely to be followed by certain other conditions, and thus one becomes able to predict the weather with some accuracy even without a weather map. The map, however, always is helpful.

[1] All institutions where the weather is studied should post the daily weather maps in a place where they can be consulted easily. Several consecutive days' maps should be kept strung on a wire, so that the progression of weather conditions across the country can be followed and studied. The United States Weather Bureau will send the daily weather maps to any school upon application to United States Weather Bureau, Washington, D.C., or the nearest Weather Bureau forecast center.

[2] *Report of the Chief of the Weather Bureau*, 1919–1920, p. 11. U.S. Department of Agriculture.

7. The *time* at which predicted weather changes are likely to occur depends largely on the rapidity with which the HIGHS and LOWS move eastward. Note on Figures 156 and 157 the distance moved in twenty-four hours of March 29 pressure areas: (*a*) the HIGH centering over Montana, and (*b*) the LOW centering over Minnesota.
8. Predict the weather for March 31, 1923, for Omaha. For Albany, N. Y.
9. If a station of the United States Weather Bureau is accessible, visit it and observe the instruments and the methods of recording weather data. Talk with the official in charge concerning the service of the Weather Bureau to the community in connection with:
   a) Storm warnings for vessels.
   b) Low temperature prediction for fruit and vegetable growers and shippers.
   c) Snow prediction for street-cleaning departments and for railroad dispatching and operating departments.
   d) Fair-weather prediction for outdoor events such as baseball games and picnics.
   e) The condition of the roads.
   f) Flood warnings and the prevention of loss of life and property.
   g) Evidence for use in courts of law.

   Read pages 173–180, "The United States Weather Bureau."

CLIMATES OF HIGHER ALTITUDES IN THE MIDDLE LATITUDES

1. What are the several ways in which the climate of middle latitude highlands is significant to dwellers in lowland regions?
2. On the copy of the world-map of climatic regions used for middle latitude lowlands, color the middle latitude highlands in purple. Consult world-maps of temperature and relief.
3. Note on an atlas map the location of Glacier National Park, of Yellowstone National Park, and of Mount Ranier National Park. Name some other well-known mountain resort areas. What characteristics make these areas desirable for recreation purposes? See Figures 165–166, and 46.
4. Compare Figures 167 and 168. How do the areas in the United States at present forested differ from those which it is proposed to keep permanently in forest? Are most of the latter in lowlands or in highlands? Is this because the climate of the highlands is more favorable to forest growth than that of the lowlands?
5. A number of the forest reserves shown in Figure 169 are less important as sources of timber than as regulators of streams which head in mountains and flow out on to desert or semi-arid plains or plateaus. Why? See Figures 142 and 149. Why is the rainfall of mountain areas adjacent to dry lowlands likely to be considerable?
6. In many parts of the world, flocks and herds are driven up into the mountains during the summer. Why should grazing in the higher mountains be limited to summer? Read "High Altitude Climates in the Middle Latitudes" (pp. 180–182), and see Figure 170.
7. In so far as there is cultivation of land in middle latitude mountains, where and why is it concentrated? Read "The Agriculture of Mountain Valleys" (pp. 182–183), and see Figure 171.
8. In most mountain regions much of the cultivated land is in hay or grass (Figs. 171–172) rather than in grains or other tilled crops. Why?
9. Railroads in mountain regions are likely to encounter especial difficulty in operating trains in winter across passes. Why? See Figure 173.

REVIEW OF MIDDLE LATITUDE TYPES OF CLIMATES

1. Can you trace any general system in the distribution of middle latitude types of climate? Compare Figures 1 and 150.
2. Do middle latitude climates differ more strikingly in rainfall or in temperature? Recall the chief characteristics of the various types in seasonal temperatures and seasonal rainfall.
3. Study the table "Arable Land of the Earth," p. 168, in connection with Figure 1. Does there seem to be any relation between proportion of land area cultivated in the middle and low latitudes and climate?

HIGH LATITUDE CLIMATES

1. How does the world-map of density of population show the high latitudes to compare with the other latitudes? Why are the high latitude regions not more densely populated?
2. How do midsummer days in the high latitudes compare in length with those in the middle and low latitudes? Why? See Figures 66 and 67.
3. In view of the long days, why does not temperature in the high latitudes rise higher than is indicated by Figures 38–40 and world-maps of temperature? Consult again Figures 66–68.
4. Determine from the world-maps the variations from place to place within the high latitudes of temperature and rainfall which differences within the high latitudes are more significant for human activities?
5. What seems to be the chief cause of the variation in temperature from place to place in the high latitudes?
6. What does the world-map of natural vegetation suggest as to the validity of your answer to Question 4?
7. On a fresh copy of the world-map of climatic regions, color those regions having the lower high latitude type of climate.
8. Read about the Hudson Bay Company in one of the standard encyclopedias. From which types of climate do you suppose most of the company's furs come?
9. How do the regions of lower high latitude climate compare with other high latitude regions in their possibilities of economic development? Why? Just what are the possibilities? Suggest reasons why these regions have not been more fully developed. Read "The Lower High Latitude Type of Climate" (pp. 183–184), and see Figure 6.
10. On the same copy of the world-map of climates, color the regions having the subpolar and the polar types of climate.
11. Several European companies are mining coal in Spitzbergen. Is this industry an outgrowth of the climate of the region? Do you suppose that climate affects mining operations?
12. Work out the succession through the year of the following seasons at Spitzbergen: (*a*) continuous darkness, (*b*) continuous light, (*c*) alternating night and day with the days growing longer, and (*d*) alternating night and day with the days becoming shorter. Use Figures 66 and 67.

UNION LIBRARY

13. Do you believe that the Eskimo's failure to develop a high civilization is due to imperfect utilization of the natural possibilities of the regions in which he lives? Be prepared to defend your point of view. See Figures 174–179, and read "The Subpolar Type of Climate," pp. 184–185.
14. What difficulties does climate impose on polar exploration? Read "The Polar or Ice-Cap Type of Climate" (pp. 185–188). See Figure 180.

Library of
Davidson College

CHAPTER III

LAND FORMS AND SOILS

COMPARISONS BETWEEN LAND FORMS, SOILS, AND CLIMATE

1. Do you suppose that land forms are of greater or less significance than climate in helping to determine the economic possibilities of a region? How about soils?
2. Would you expect to find similar land forms or soils in widely separated parts of the earth?
3. Within a climatic region would you expect to find uniformity or variety in land forms? Why? In soils? Why?
4. If there be variety in land forms and in soils within a climatic region, is the utilization of the land in this region likely to be uniform or varied?
5. Do you think that two widely separated areas of similar land forms, soils, and climate are likely to be used in about the same way? Suppose the areas have similar land forms and soils but different types of climate?
6. From the standpoint of economic geography does it seem desirable to distinguish *types* of surface features, in somewhat the same way that types of climate have been distinguished?
7. In so far as natural environment has a bearing on economic activities, particularly on cultivation of the land, the grazing industry, the forest industries, and transportation, it is quite evident that both land forms and climate are of prime importance. Within a region throughout which there is a broad similarity of climate there is a tendency toward broad similarity in economic activities; similarly, but in considerably less striking manner, there is a tendency toward uniformity in economic life within a region of uniformity in land forms. In cases where climatic and surface uniformity coincide, there is a stronger likelihood of economic uniformity than in cases where there is diversity of land forms within a climatic region, or diversity of climate within a land-form region. Great care must be exercised in geographic study not to overemphasize the significance of any one element of the natural environment.

MAJOR LAND FORMS

1. From time immemorial people have recognized four major types of land forms—plains, hills, mountains, and table-lands (plateaus). See Figure 7. How would you describe each of these kinds of country?
2. Would you expect life-conditions to differ strikingly in these four types of land forms? How and why?
3. Does the bulk of the earth's population live in mountains, on plains, in hills, or on plateaus? Compare Figures 7 and 8. Are any well-populated mountain or plateau regions shown on the maps? Why do you suppose these regions are exceptions to the general rule of sparsity of population in highlands?

MOUNTAINS[1]

1. Is a large or small proportion of the area of most mountain regions under cultivation? Why? See Figures 181 and 182.
2. Where is most of the cultivated land in mountain regions? Why? See Figures 182–184, and 171.
3. Why do you suppose the following practices are characteristic of mountain agriculture?
   a) Terracing of fields (Fig. 181).
   b) Devotion of a large share of the cultivated area to hay or permanent meadow (Figs. 171 and 172).
   c) Raising relatively hardy grains which mature in a few months, e.g., barley and oats.
4. Is the rearing of live stock a characteristic mountain industry? How do you suppose it compares in importance with cultivation of land in most mountain regions? Why?
5. Why are the herds shown in Figure 170 taken down to the villages in the valleys in the winter? Why are these herds not kept in the valleys in the summer?

[1] In this and the subsequent exercises on land forms careful and repeated reference should be made to appropriate atlas maps. Particularly should the location of all areas referred to in exercises, textual materials, and illustrations be looked up on the largest scale atlas maps available.

6. Would you expect to find in many mountain regions seasonal migration of flocks and herds between lower valleys and upper mountain slopes? Read "The Pastoral Life of the Mountain" (pp. 192–196).
7. Do you suppose the potential water-power of mountain regions constitutes a large or a small proportion of the earth's total water-power resources? Why?
8. The water-power resources of the Alps are much larger than those of the Atlas Mountains. Why do power possibilities differ markedly in different mountain regions?
9. How do you suppose the following mountain regions compare in (*a*) water-power possibilities, and (*b*) present-day development of water-power: Himalayas, Alps, Atlas, mountains of Japan, Cascades, mountains of Madagascar, mountains of the East Indies?
10. Does a comparison of Figure 169 with a relief map of the United States show most of the government forest reserves to be in mountain regions? How do you suppose this distribution of government reserves in relation to land forms compares with the distribution of forest land when Europeans first explored the country? Why has the distribution changed so markedly in a few hundred years?
11. Is change of the character outlined in the preceding question confined to the United States? What conditions have brought about such change?
12. The scenery of several mountain regions constitutes a real economic resource in connection with the resort business. Cite some examples of such mountain regions. What changes are likely to accompany the development of a resort business similar to that shown in Figures 165 and 166, in
    a) Land utilization in the nearby valleys?
    b) Number of permanent inhabitants of the locality?
    c) Prosperity of the inhabitants of the locality?
    d) Development of transportation facilities between the locality and the outside world?

    Account for each change mentioned.
13. What are the chief elements making up the attractive scenery in each of the mountain regions shown in Figures 165 and 166, 185–187, 192 and 193?
14. Many mountain regions have scenery which is called "alpine," from its extensive development in the Alps. Some of the elements of Alpine scenery are:

a) Perpetual snow fields on the higher levels, and glaciers at the upper ends of some of the valleys (Fig. 185).

b) Serrate or jagged peaks along stream divides (Fig. 185).

c) Deep U-shaped valleys, with much smooth rock surface in their courses (Fig. 186).

d) Steep-walled valley heads in the shape of theaters, called "cirques" (Fig. 187).

e) Lower ends of valleys partly filled with moraines.

f) In the Alps, the Northern Rockies, and the Southern Andes, many long, narrow lakes extend from the heart of the mountains, where they lie in ice-scoured valleys and may be several hundred feet deep (Fig. 188), to the border of the mountains, where they lie in moraine dammed and partially drift-filled sections of valleys and are only a few score feet deep (Fig. 189).

g) Down-valley from the moraines there may be flat plains of glacial outwash (Figs. 189 and 190).

"Alpine Scenery," which is co-extensive with glaciated mountains, is discussed on pages 196–197, and its distribution is suggested by Figures 240 and 191.

15. Striking elements in the scenery of some mountain regions are peaks of the type shown in Figures 192 and 193. Such "volcanic cones" are to be found also on certain plains and plateaus. They are built of material ejected during volcanic outbursts.

16. The varied topography of mountain regions is the result of the work of various agencies. Read "The Origin of Mountains" (pp. 197–198).

17. Where would you expect to find most of the roads and railroads in mountain regions? Why? Do Figures 182 and 194 confirm your supposition?

18. From the standpoint of people living outside mountain regions, an important rôle played by mountains is that of barriers to trade. Routes through mountain regions commonly follow what lines?

19. Read "Functions of Mountain Passes" (pp. 198–202). On an atlas map find each of the passes considered and be prepared to discuss its significance in connection with routes across mountains. See Figure 195.

20. The barrier quality of mountains expresses itself for many years after the completion of tunnels piercing the mountains, in (*a*) the interest costs, and (*b*) the principal costs of bonds used to raise

money to construct the tunnels. How does this fact accord with the notion that a tunnel represents a complete conquest of Nature?

21. The following questions on the Skykomish and Chiwaukun (Wash.) topographic maps [posted], illustrate in detail typical conditions in mountain regions. Large-scale topographic maps of this type are highly useful to geographers, and facility in reading and interpreting them should be acquired as rapidly as possible. The instructor of the class will explain in conference whatever is not clear in the symbolism employed on the maps.

a) Find the location of this area on a large-scale atlas map. In which type of major land form does it lie?

b) What is the scale of the maps? In what ways is it shown on the lower edge of the maps? What is the value of each of these expressions of scale? How many square miles are covered by these maps?

c) How is a contour line represented on the map? What does it show?

d) What is the meaning of the phrase at the bottom of the map, "Contour interval 100 feet"?

e) In cases where a contour line follows the sides of a valley and crosses the valley, does it run upstream or downstream from the crossing? How can you tell? How do contour lines represent spurs on mountain slopes?

f) What land-form feature does the line of the Great Northern Railroad follow across most of the area? Why?

g) By what means does the railroad cross the crest of the Cascade Range? Why? What is the elevation above sea-level of the crest of the range? Of the railroad at the highest point?

h) Note the peculiar pattern of the route west of the Cascade Tunnel to Skykomish. What is the approximate difference in elevation between these two places? What is the relation between this difference in elevation, the airline distance between the two places, and the route followed by the railroad?

i) Where do trails, shown by dashed lines, cross the crest of the Cascade Range? Why do you suppose these trails follow the routes they do?

j) In which sections of the area covered by these maps are most of the roads (shown by double lines), the houses (small black squares), and the towns (shown by closely set roads and houses)? Explain the distribution noted.

k) In so far as there is cultivated land in the area, where do you infer that it is? Why?

l) The western half of the area covered by these maps is much more heavily forested than the eastern half. Examine Figures 4, 5, and 140, in connection with a relief map of the United States, and suggest an explanation for this difference in forest conditions.

m) What difficulties do you suppose attend logging and lumbering in this mountain area?

n) Do you suppose grazing is more important in the eastern or in the western half of the area? Why?

o) Suppose you were to take a vacation climb from the valley of the Snoqualmie River (shown at the southern edge of the map just west of the crest of the Cascade Range) to Summit Chief Mountain. What route would you probably follow? Which would be the more difficult part of the climb? When you stood on the summit of the mountain, how far below you would the lower ends of the glaciers (shown by wavy blue lines) be? Would the other mountain peaks in the vicinity be above or below you? Could you see the line of the Great Northern Railroad at any point? What features would add attractive elements to the scenery, besides mountain peaks and slopes, valleys, forests, glaciers, and snow fields?

p) The Cascade Mountains are much less densely populated than the Alps. Suggest reasons for this fact.

PLAINS

1. Suggest reasons why many plains regions are densely populated, whereas most mountain regions are not.
2. By comparing Figures 7 and 8, determine which major plains are densely populated, which moderately, which sparsely, and which have practically no population. Do you suppose that the chief cause for the difference in density of population of these regions is difference in land forms? See Figures 1 and 141.
3. How and why does the agriculture of plains differ from that of mountain regions in the following respects?
   a) Proportion of the area under cultivation (Figs. 141, 195*b*, 134, and 186).
   b) Distribution of cultivated land (Figs. 128, 182, and 171).
   c) Ease with which farming operations are carried on (Figs. 195*b* and 183).
   d) Practices employed in tillage (Figs. 259 and 181).
   e) Wealth of agricultural population (Figs. 246 and 181).
   f) Types of crops grown?
4. By comparing Figures 7, 1, 6, and 8 determine those plains regions in which you believe the grazing industry is more important than cultivation of the land. Be prepared to defend your findings.
5. Are logging operations easier on plains, or in mountain regions? Why? Do you imagine that, in the past, more of the world's timber supplies have come from plains or mountains? What is likely to be the tendency in future? Why?
6. Over the earth as a whole, do you think plains or mountain regions are more suitable for permanent forest reserves? Why? What kinds of areas on plains may well be kept in forests? See Figure 168.
7. How and why does the railroad net differ in the plains and the mountain sections of the United States, as shown by a comparison of Figures 196 and 7? Do you suppose a similar difference is to be found between plains and mountain regions in other countries?
8. Few plains regions have such a close network of railroad lines as has the area between Pittsburgh and Omaha. Which plains shown in Figure 7 have fairly close rail nets? Examine appropriate atlas maps.
9. Why have so many plains regions of the earth a very incomplete railroad net or no lines at all?

10. What is the characteristic difference in the pattern of railroad routes on plains and in mountains? Read "Land Routes of Trade and Travel" (pp. 202–204).
11. What typical contrasts are there between railroads in plains regions and in mountain regions:
    a) In cost of construction?
    b) In directness of route?
    c) In tunnel construction?
    d) In number of bridges?
    e) In number and size of cuts and bills to make a desirable grade?
12. Would you surmise that the cost per mile of railroad operation is higher in the western mountain section of the United States, or in the central and eastern plains sections? How about the average mileage obtained by an auto-truck from a gallon of gasoline in Western Colorado as compared to Illinois? How about the cost per mile of railroad- and road-building and upkeep in Western Montana as compared to Iowa? Why?
13. Do you believe facts of the sort suggested in the preceding question are of more or less significance than density of population and productivity in explaining the heavier traffic on railroads in plains regions than on those in mountain regions?
14. Are most navigable rivers in plains or mountain regions? Why? Is the presence or absence of navigable streams an important contributing factor in the development of dense populations in plains regions?
15. Are most of the world's large cities in plains or mountain regions? Why? Indicate on Figure 7 the location of the cities listed in the table on page 189.
16. Examine the atlas relief maps and density-of-population maps, and note, for the regions listed below, all the contrasts you can: Ganges-Indus Plain *vs.* Himalayas, North European Plain *vs.* Alps, Ukrainian Plain *vs.* Caucasus, Pampas *vs.* adjacent Andes, North China Plain *vs.* mountains of Western China, Dividing Range of Australia *vs.* plains just west of the Dividing Range, Amazon Plain *vs.* Andes of Ecuador and Peru, plains of Turkestan *vs.* Hindu Kush–Pamirs-Tian Shan, Siberian Plain *vs.* Altai and associated mountains.
17. Study the Findlay (Ohio) topographic map [posted] as illustrating many typical plains conditions.

a) Locate the area on an atlas relief map.

b) What is the scale of the Findlay map? How does it compare with the scale of the topographic maps studied in the preceding exercise?

c) How many square miles are included on the Findlay map? How does this compare with the area covered by each of the mountain maps just referred to?

d) What is the contour interval of the Findlay sheet? Why do you suppose the interval is not the same as that used on the mountain maps?

e) Do you think a larger or a smaller proportion of the land is under cultivation in the area about Findlay than in the Cascade Mountain area studied? Why? Is there any difference in the distribution of cultivated land?

f) Assuming that each building not in villages or cities represents a farmstead, calculate the approximate average size of farms in the Findlay area.

g) What is the characteristic layout of the roads shown on the Findlay map? Of the railroads? How does each differ from the routes through the mountain area? Why?

HILL COUNTRY

1. Intermediate in character between mountain regions on the one hand and plains regions on the other, and yet unlike either in certain significant respects, are regions of hilly configuration.
2. Do the location and character of routes of trade and travel in hill regions more closely resemble those of plains or those of mountain regions? See Figures 197 and 199. Is the cost of construction and upkeep of railroads and roads higher in hill country than on plains? Than in mountain regions? Why?
3. Assuming a climate conducive to tillage, would you expect to find a higher percentage of the land under cultivation in hill country, in mountains, or on plains? Why?
4. Within a hill region, where would you expect to find most of the cultivated land? See Figures 197–203.
5. The terracing of slopes for cultivation in hill country or in mountain regions entails a tremendous amount of labor, both in making the terraces and in maintaining them intact against slope wash. Only under what conditions of population and economic organization would you expect it to be done? Do Figures 204 and 181 support your contention?
6. Destructive soil wash and gullying are likely to be serious agricultural problems in hill country. Why? See Figure 202.
7. Why is the industry pictured in Figure 205 characteristic of many hill regions? Seasonal migration of herds of the sort discussed under mountains is not characteristic of hill regions. Why?
8. The people in the hill country of Eastern Kentucky and of adjacent states commonly are called "mountaineers." They possess many of the traits characteristic of people who live the restricted economic and social life which exists in varying degree in most hill and mountain regions. Read "Contrasts between the Hill Country and Plain, Exemplified by the Kentucky 'Mountains' and the Bluegrass" (pp. 204–208). Study the Paintsville (Ky.). and Georgetown (Ky.) topographic maps [posted] and examine Figures 199–202, 232, 281, and 366.
9. What proportion of a region would you say must be hilly in order that the term "hill country" rather than "plain" can properly be applied to it? Some parts of the lowland areas shown on the so-called physical or relief maps in the atlas are hill country rather than plains. Why is it impossible on maps of this type to distinguish between low hill country and plains?

10. The term "hill country" is general and includes a considerable variety of land forms. Relief may range from two or three hundred to perhaps two thousand feet, and the arrangement of the hills and valleys may differ greatly from region to region. Compare Figures 197–205, and the Paintsville (Ky.), Harrisburg (Pa.), and Eminence (Mo.) topographic maps [posted]. In describing a given hill region one should note the proportion of upland levels and valley-bottom flats to slopes, the steepness of the slopes, the approximate difference in elevation between hilltops and valley bottoms, and the arrangement of the valleys. What bearing is each of these points likely to have on the economic utility of a region, particularly on land utilization and the location and character of transportation routes?

PLATEAUS

1. As you think of plateaus or tablelands, how do they differ in physical characteristics from (*a*) mountain regions, (*b*) hill country, and (*c*) plains? In each case how would you expect these physical differences to be reflected in economic life?
2. Examination of the chief plateaus or tablelands of the earth reveals the fact that each possesses several of the following physical features: (*a*) a general elevation above sea level of from 2,000 or 3,000 to 15,000 feet; (*b*) extensive areas that are flat or relatively smooth; (*c*) mountain ranges inclosing or partly inclosing the plateau; (*d*) mountain ridges interrupting its general flatness; (*e*) extensive piedmont alluvial plains at the base of the mountain ranges; (*f*) deep canyons cut into and still further interrupting the general plateau surface; (*g*) an "interior drainage system" of streams which head in the mountains, flow down on to the plateau, and there dry up; (*h*) light to scanty rainfall; (*i*) an abrupt topographic transition on at least one side of the plateau to higher mountain or lower plains.
3. So far as you can tell, which of the features noted in the preceding questions are characteristic of each of the following regions: Spanish Plateau, Abyssinian Plateau, Arabian Plateau, Plateau of Iran, Plateau of Asia Minor, Colorado Plateau, Columbia Plateau, Plateau of Bolivia, Plateau of Mexico. Consult the relief maps of the continents in the atlas, and the rainfall maps.
4. Grazing is an important industry over the larger part of most plateaus. Suggest reasons for this fact.
5. Most cultivation on arid or semi-arid plateaus is carried on by means of irrigation, on "piedmont plains" at or near the base of the associated mountain ranges (Fig. 88). Why is this natural?
6. Is the density of population essentially the same in all the plateaus listed in question 3?
7. The term "plateau" sometimes is applied to certain regions which are in fact hill country or plains; e.g., the "Laurentian Plateau," the "Piedmont Plateau" of Southeastern United States, the "Allegheny and Cumberland Plateaus," and the "Ozark Plateau." Why are these areas not true plateaus? Examine the Charlotte (N.C.–S.C.), Paintsville (Ky.), and the Eminence (Mo.) topographic maps [posted], and the atlas relief maps of the United States and Canada.

8. What typical plateau conditions are illustrated in Figures 88, 206 and 207?
9. Study the Chino, Echo Cliffs, Kaibab, and San Francisco Mountains (Ariz.) topographic maps [posted], with the following questions in mind.
   a) Where is the area, as shown on a large-scale atlas relief map?
   b) How does the area covered by each sheet compare with that covered by the maps used in preceding exercises on mountains, plains, and hill country?
   c) What is the contour interval?
   d) How far below the general level of the plateau is the Colorado River?
   e) What is the gradient of the river in feet per mile? Is it navigable?
   f) Why cannot the water of the Colorado River be used to irrigate the plateau lands? Why must the plateau lands be irrigated if they are to be cultivated?
   g) Why are there so few roads (shown by single black lines) in the area covered by the maps?
   h) In laying out railroad lines, engineers try to avoid crossing canyons of the type shown on these maps? Why? In case it is imperative to build a railroad across such a canyon, the route selected is almost sure to follow a tributary valley to the bottom of the main canyon, thence up- or downstream to a tributary from the opposite bank, up which it can make its way to the plateau level. Why cannot the crossing be made direct?
10. Certain features which are typical of many plateaus are well shown on the Carson Sink (Nev.) topographic map [posted].
   a) Flat plains, on the lower portion of which are shallow salt lakes (why salt?) which shrink and expand with the amount of water brought to them by streams, and with variation in evaporation. Examples are Carson Sink, Carson Lake, and the temporary lakes on Alkali Flat, Eightmile Flat, Fourmile Flat, Labov Flat. In some cases the accumulations of salts on these flats are of commercial value; note the area marked Borax Field.
   b) Streams which head in mountains but which flow only a short distance on the plains and then disappear. In this area many of these streams are intermittent, as shown by the dash-and-

dot blue lines. Why are these streams intermittent? Why do most of them entirely disappear on the plain? The Carson River, which feeds Carson Sink, is perennial. Consult an atlas map to discover why. What do you infer as to the relation between the Carson River and its distributaries, and the presence of many houses in the area about Fallon? Why are there so few houses along most of the small streams flowing out from the mountains shown on this map?

11. By way of comparing plateaus with the other types of major land forms read "Contrasts among the Major Land Forms" (pp. 208–211), and study the map, Figure 7. Then list and arrange in parallel columns the economic assets and the economic handicaps of each type of major land form. Hand in this list within a day or two.

MINOR LAND FORMS

1. If any *major* land-form region be examined in detail it will be found to vary considerably from place to place in its land forms, soils, and surface-water features, and consequently in its economic utility. In several exercises which follow, certain types of *minor* land forms will be considered. In the nature of the case, how do minor land forms compare in area with major land forms?
2. Do you think the same type of minor land form might be found in several different places within a given major land-form region?
3. Any statements of the relations between major land forms and economic life are bound to be broad generalizations, whereas the relations between minor land forms and economic activities can be stated in less general terms. Why?
4. Would you expect to find economic life essentially the same in a given type of minor land-form area all over the world, in spite of wide differences in nationality, culture, and traditions?

FLOODED ALLUVIAL PLAINS—VALLEY FLOODPLAINS AND DELTA PLAINS

1. Figures 208–211, and the Galena (Ill.), the Chester (Ill.–Mo.), and the Natchez (La.) topographic maps [posted] show sections of valley "floodplains," so named because they are overflowed nearly every year at time of high water. What is the width of the Mississippi Valley at Chester? At Natchez? How do these dimensions compare with the width of the Appalachian Hill Country or the Rocky Mountains, as shown in Figure 7?
2. What is the average elevation above the stream at low water of the floodplains shown on the maps just referred to? What is the general surface configuration of the floodplains, as compared to the land farther back from the river? Select two points on the floodplain, one ten miles below the other. How do they compare in elevation?
3. So far as land form is concerned, would it appear that cultivation of floodplains is easy or difficult?
4. It is unnecessary to fertilize field on floodplains. Why? In this respect are such floodplains like or unlike deltas?
5. What problems would you expect floodplain farmers to have?
6. How would you expect floodplain farms to compare in desirability with nearby upland farms in dry years? Why? In wet years?
7. Many floodplain areas are not cleared for cultivation, as may be seen by reference to the Galena, Chester, and Natchez quadrangles, and to Figure 210. Suggest reasons for this. Under what conditions may it eventually be profitable to clear and cultivate such areas?
8. Many areas on floodplains are so wet even at low water, and are flooded for so long a period each year, or they are of such recent origin, that they do not have natural forest cover. Cultivation of these mud or sand flats is ordinarily impracticable (Fig. 211). Why?
9. Examine Figure 212, and locate, on a large-scale atlas map, the area shown. How does the density of population in Hungary compare with that of the Mississippi Valley? What bearing has this fact on the problem of protecting alluvial lands from overflow?
10. Notice the location of the railroads on the valley floodplains shown on the Galena and Chester topographic maps. Why do you suppose the railroads hug the inner edges of the floodplain?

11. Examine the posted topographic maps[1] of the Lower Mississippi River country. What is the general elevation of the land with reference to sea level? With reference to the streams which traverse the area? What relation have these facts to the large areas of wet land shown on the maps? Note that some of the wet lands are fresh-water marshes, whereas others are salt marshes. Where are these two types of land, and why?
12. What would seem to be the chief natural handicap to cultivation of the land in the Lower Mississippi River country?
13. Why is it especially difficult to drain land in this area?
14. Note the following facts:
    a) The Mississippi and its tributaries carry down from their upper courses enormous quantities of sediment. From an atlas map determine the extent of the drainage basin of the Mississippi System.
    b) The current of the Lower Mississippi is relatively slow. Why?
    c) At times of high water most of the Lower Mississippi country is submerged. Why does this happen even when the river rises only a few feet?
    d) The Lower Mississippi country, to a depth of hundreds of feet, is composed of fine-grained material, without gravel or rock.
    e) The plains of The Lower Mississippi are growing slowly seaward. Why? See Figure 213.
    f) These plains are almost at sea level. How does this follow from the conditions outlined in the preceding paragraphs?

    What do these facts suggest concerning the origin of the plains of the Lower Mississippi? Be prepared to explain carefully your reasoning.
15. Where it is sufficiently drained, the land in the Lower Mississippi country is very productive, for the soil is extremely fertile. What characteristics of the soil contribute to its productivity?
16. Most of the cultivated land in the Lower Mississippi country borders the rivers. This land is a little higher, and therefore better drained, than the land back from the rivers. Do the topographic maps show this fact clearly? These strips of slightly higher land near the streams seem to have been formed by the same process

[1] East Delta, West Delta, Cheniere Caminada, Timbalier, Forts, Quarantine, Fort Livingston, Creole, La Fortuna, Lake Felicity, Dulac, Dime, Pt. a La Hache, Barataria, Cut Off, Houma, Chandeleur, Bodreau, Shell Beach, St. Bernard, New Orleans, Hahnville, Lac Des Allemands, Cat Island, Toulme, Rigolets, Chef Menteur, Spanish Fort, Bonnet Carre, Mt. Airy.

by which the entire area was built up, viz., by deposition from flood waters. At times of high water some deposition of sediment takes place over the entire plain. Why? Most of the sediment is deposited close to the lines which mark the stream banks at ordinary stages of the river. Why? This results in the accumulation through the centuries of somewhat thicker deposits near the streams than back from them. These strips of slightly higher land are called "natural levees."

17. Where on the Mississippi Delta would you expect to find most of the roads and farmhouses and some of the railroads? Check your answer by consulting the topographic maps.
18. Farmers in many delta districts substitute boats for wagons (Fig. 214). Why?
19. Note the peculiar shape of land holdings shown in Figure 215, and suggested on some of the topographic sheets. These land holdings date from the days of early settlement, long before the construction of railroads. Why do you suppose the land holdings took this form?
20. In what type of location do you suppose most of the artificial levees in the Lower Mississippi country have been constructed? For what two very good reasons were the levees put where they are?
21. What is the great danger in connection with artificial levees? See Figures 216–219, and read "Floods in the Lower Mississippi Valley" (pp. 211–215).
22. Why is it difficult to drain most wet floodplain and delta areas even after the construction of levees to guard against overflow at high stages of the river? Examine the topographic maps with this question in mind.
23. The map, Figure 220, shows the location of several plains which are similar to the "delta plain" of the Lower Mississippi River. See Figures 221 and 222. Does it seem likely that the same sorts of crops would be grown on all these delta plains? Why?
24. Compare the density of population of the delta plains shown in Figure 220. Suggest reasons for the differences.
25. The soils of most annually overflowed valley floors and deltas are deep, even though the annual film of deposition laid down at high water be but a fraction of an inch or at most a few inches thick. What does this suggest as to the length of time involved in the development of delta plains and floodplains?
26. Would you expect to find a sharp division line between the delta and the valley floodplain of a given stream?

27. In what ways is the site of New Orleans advantageous for a large city, and in what ways is it disadvantageous? Examine an atlas map of the United States in addition to the topographic sheets.
28. On which of the delta plains shown in Figure 220 are there large cities? Look up these cities on the largest scale atlas maps available. What advantages and disadvantages of site have these cities in common? Read "Delta Cities" (pp. 215–217), and see Figures 219, 223, and 224.
29. Do the topographic maps show few or many bridges? Why?
30. Why are there fewer cities on valley floodplains than on deltas? Compare the location of Natchez (on the Natchez map), and Chester (on the Chester map), with that of New Orleans.
31. Cairo, Illinois, is a typical floodplain city. In what respects would you suppose its problems to be similar to those of delta cities?

WELL-DRAINED ALLUVIAL PLAINS

1. Examine the lowlands of Northern India on the largest scale relief map available. Each river on this broad plain has its own floodplain, from a fraction of a mile to several miles wide. Between these floodplain strips there are extensive tracts of land not flooded by the streams at high water. Figures 80 and 81 show such land in India. These unflooded tracts are only a few feet higher than the floodplains, and are similar to them except that they are better drained. The materials of these interstream tracts have all the characteristics of stream-laid deposits. It thus appears that the entire lowland plain between the Himalayas and the hill country of Peninsular India is composed of "alluvial" or stream-laid deposits. Through the ages deposition from streams has taken place at one time or another on every part of the area. The three types of alluvial deposits—(*a*) deltas at the mouths of the Ganges and the Indus, (*b*) floodplains along the present-day streams, and (*c*) the higher, unflooded, interstream tracts, sometimes called "old alluvium"—are similar in origin, but widely different in utility. Why are the first two types called "recent alluvium" and the third type "old alluvium"? What would seem to be the advantages of each for cultivation?
2. Re-read so much of "Agricultural Practices in India" (pp. 116–118), as deals with the flooded and well-drained alluvial plains.
3. Look up the following plains on the largest scale relief map available in the atlas: Pampas of Argentina (Fig. 225), Great Plains of the United States, Amazon Lowlands, Llanos, plains of Southern Russia, Hungarian Plain, plains of West Turkestan, plains of Southwestern Siberia, Manchurian Lowlands, lowlands of Eastern China, plains of the Darling Basin, Po Basin, Mesopotamia. Much of the surface material of each of these plains consists of well-drained alluvium. For example, on the Hungarian plain "old alluvium" lies 400 feet thick in places. What are the size and distribution of the streams that traverse each of these plains?
4. Would you expect the average density of population in these plains to be about the same or notably different? What do the population maps show?
5. What type of climate has each of these regions? Would you expect those which have similar climates to have the same density of population? What conditions other than surface features and climate might have a bearing on density of population?

PIEDMONT ALLUVIAL PLAINS

1. Piedmont alluvial plains, as the name indicates, occur at the foot of mountains. They are especially well developed at the base of mountains in arid or semi-arid regions, for reasons which are suggested in the following questions.
2. In Southern California there is a piedmont alluvial plain, a part of which is well represented on the Cucamonga (Calif.) topographic map [posted] and in Figure 231. At the base of what mountain range does this plain lie?
3. What does the geographic cross-section, Figure 226, suggest as to the origin of the plain.
4. How do the materials of this plain differ from place to place, and why?
5. What bearing might this difference have on the suitability for cultivation of the different parts of the plain?
6. What becomes of the water of the streams that flow down onto the plain from the mountains?
7. The lands of the plain are irrigated in part with water drawn from local wells. The rainfall on the plain is scanty, but that in the mountains is fairly abundant. What undoubtedly is the source of most of the ground water drawn from these wells?
8. Practically all the irrigation water is distributed through covered ditches. Why do you suppose the ditches are covered?
9. How does the configuration of the plain aid irrigation?
10. From your knowledge of Southern California, what do you suppose are the chief crops in the Cucamonga District?
11. Frost hazards to delicate crops in the Cucamonga District are lessened by the excellent "air drainage," particularly on the higher portions of the piedmont plain. Read "Piedmont Plain Agriculture in Southern California" (pp. 218–221), and see Figures 226–231. Would you expect to find good air drainage on piedmont plains in other parts of the world?
12. Note on the Cucamonga topographic map the contrasts between the plain and the mountains in number of roads, houses, and towns, and in the distribution of roads. Explain these contrasts.
13. The mountains originally were forested in places, the plains not. Suggest the cause for the contrast.
14. Suggest at least three reasons why it is desirable to have a forest reservation in the mountains.

15. Figure 230 is a general view of part of the extensive piedmont alluvial plain at the west base of the Wasatch Mountains. Why should the crops grown in this area be different from those grown on the piedmont plains of the Cucamonga District? In what important respects is the agriculture of the two areas similar, and why?

COASTAL PLAINS OF UNCONSOLIDATED MARINE SEDIMENTS

1. The Atlantic and Gulf Coastal Plain of the United States (Fig. 232), the coastal plain of Eastern India north and south from Madras, the plain of the Garonne in Southwestern France, and the coastal plain of Eastern Mexico north from Vera Cruz, are illustrations of a type of minor land form of which there are numerous other examples in various parts of the earth. What do the large scale atlas relief maps show as to the elevation of these plains above sea level?
2. The Rehoboth, Millsboro, Cape Henlopen, and Cedar Creek (Del.) topographic maps [posted] represent typical land forms on a coastal plain. How do they compare in smoothness with alluvial plains?
3. Note that a considerable percentage of the area covered by these topographic sheets is wooded, although the demand for cultivable land in Eastern United States is pressing. Sandy soil is the explanation. Sandy soil is typical of all the plains referred to in question 1; although there is a good deal of variation in the fertility of the soils of these plains, they are at best only of medium richness, and many of them are very poor. Much of the land on the South Atlantic and Gulf Coastal Plain of the United States, the so-called "pine barrens," remained almost unoccupied until toward the end of the nineteenth century, when commercial fertilizers came into general use.
4. Note the coastal marshes on the area covered by the topographic sheets. Such marshes are typical of the seaward margins of all the plains referred to in question 1. A good deal of the wet land in the United States is of this type. See Figure 233 and the table, "Land in the United States Unfit for Cultivation without Drainage" (p. 221). In places coastal marshes have been reclaimed (Fig. 234). Read "Reclamation of Tidal Marshes" (pp. 222–226). See Figures 235 and 236, and read "Reclamation of Wet Land in the Netherlands" (pp. 226–227).
5. On the topographic sheets posted, note the zone of sand dunes along the coast. Do the maps suggest a use to which this dune bordered coast is being put? Similar dune belts are found on most of the plains referred to in question 1, and in not a few places a similar use is made of them and the adjoining beach. The atlas

map of Holland and Belgium shows several famous seaside resorts along such a dune coast.

6. Not only are dune areas of little agricultural value, but their cultivation is likely to start them moving. Why? The shifting of dunes is likely to be highly undesirable. See Figures 237 and 238. (Dunes on a lake shore are similar to dunes along sea-coasts.) After reading "Coastal Dunes" (pp. 228–231), suggest measures that might be taken to halt the movement of dunes.
7. On most coastal plains of the type discussed in this exercise there are strips or patches of alluvial land. Why is this natural? How would you expect the fertility of these strips of alluvial land to compare with that of the non-alluvial land of the plain? Figure 239 shows such alluvial lands, the borders of which have been or are in process of being reclaimed from the sea.
8. Read "Origin and Characteristics of Coastal Plains of Unconsolidated Marine Sediments" (p. 231), and see the Provincetown and Wellfleet (Mass.) topographic maps [posted].

ICE-SCOURED PLAINS AND HILL COUNTRY AND MORAINE PLAINS

1. Extensive areas in the higher middle latitudes bear evidences of having been covered by ice sheets in recent geologic times. By making a comparison of Figures 240 and 7, outline the approximate boundaries of glaciated plains in North America and in Europe.
2. Within these glaciated areas there are several minor types of land forms, chief among which are ice-scoured plains and hill country (Figs. 241–243), rough moraine areas (Fig. 249), which in extreme cases are sufficiently rugged to be classed as hill country, moderately rolling moraine plains (Figs. 246 and 248), and flat moraine plains (Fig. 247).
3. Much of Canada north of the Great Lakes and the St. Lawrence River, and east of a line connecting Lake Winnipeg and Great Slave Lake (Fig. 241) consists of ice-scoured plains. Much of Finland is of the same character. Why should regions of this sort, quite apart from unfavorable climate, be largely non-agricultural, and therefore capable of supporting only a sparse population? Determine from Figures 240 and 8 the sparsely populated portions of the glaciated areas; these are in large part ice-scoured plains. Read "The Utilization of Ice-Scoured Plains" (pp. 231–234).
4. Large forest reserves have been established on the ice-scoured plains of Canada, east of Lake Superior and north of Lake Huron. What do you think of the wisdom of this action? Algonquin National Park (between 44°45′ and 46°5′ N. Lat., and 77°30′ and 79°20′ W. Long.) has been set aside for a recreation area. Do you think this action is well advised? Locate the Park on an atlas map of Canada.
5. In contrast with the ice-scoured plains of North America and Europe are the areas to the south of them, within which bedrock is covered almost everywhere with a thick mantle of loose material deposited by ice, called "till" (Figs. 244 and 245). In these areas the typical land forms are like those illustrated in Figures 246–249, and on the posted topographic maps: Pelican Rapids and Vergos (Minn.), Neshkoro and Ripon (Wis.), Ottawa and Marseilles (Ill.). "Surface Features of North America and Europe as Related to Former Continental Ice Sheets" (pp. 234–236), explains the distribution of these "moraine" plains.

6. By comparing Figure 240 with Figure 8, determine which parts of the glaciated areas of North America and Europe are well populated. Do you discover any correspondence between density of population and character of the plain (whether morainal or ice-scoured)?
7. As a result of varying proportions of steep slopes, moderate slopes, and flats, how would you expect the three types of moraine plains referred to in questions 2 and 5 to differ (*a*) in percentage of cultivable land, and (*b*) in ease of cultivation? On the topographic maps posted, pick out examples of each of these types of moraine plains.
8. Tillage of all soils on steeply sloping ground is fraught with the danger of soil depletion by sheet wash or gullying, particularly where the land is under some crop (such as corn) which requires clean cultivation. See Figure 250. In view of the high value of the land on most moraine plains, this destruction of the soil is held by some authorities to be the most serious agricultural problem of such regions. The clay content of much till makes it more subject to erosion than are many other soils because rain tends to run off over the surface rather than to sink into the ground.
9. What handicap to cultivation, other than steep slopes, is shown on much of the area depicted in the posted topographic maps?
10. The total area of poorly drained land in the glaciated portions of North America and Europe is large (see table, "Land in the United States Unfit for Cultivation without Drainage, 1920" p. 221, and Figure 233), and until artificial drainage was introduced it was much larger. See Figure 252. The United States Census of 1919 showed that 76% of all the drain tile manufactured in the country was made in the states of Iowa, Illinois, Indiana, and Ohio. Read "Drainage of Wet Moraine Land" (pp. 236–237).
11. Certain moraine plains regions, e.g., those in Michigan, Wisconsin, and Minnesota, have developed into summer resort areas. What characteristics of these areas (shown on the Pelican Rapids and Vergos maps) favor such use?
12. The soils of moraine plains vary widely from place to place in fertility, ranging from poor, stony (Fig. 251), or sandy types to the most fertile of silt or clay silt loams (Fig. 247). These variations are the result of (*a*) the original composition of the till, (*b*) the length of time the till has been exposed to weathering since the disappearance of the ice (Fig. 253), (*c*) the presence or absence of "loess," wind-blown material which in some places forms a mantle

overlying the till, (*d*) the character of the natural vegetation, (*e*) the length of time cultivation has been carried on, and (*f*) the methods of cultivation that have been employed. Be prepared to explain each of these points.

PLAINS OF GLACIAL OUTWASH

1. Within the glaciated areas of North America, Europe, South America, and Asia (Fig. 240), and at their margins, there are numerous small sandy flats ranging from a fraction of a square mile to several square miles in extent (Fig. 254). Some of these sandy flats occur as valley floors or terraces (Figs. 255 and 256), others are spread more widely and do not lie in valleys. In many cases excavations reveal the fact that these flats are underlain to a depth of a few feet or even scores of feet with stratified sandy or gravelly material (Fig. 257). Most flats of this character adjoin areas of rough or moderately rolling moraine (Figs. 256 and 189), and seem to have been formed by deposition from waters flowing from the melting edge of the ice sheet. These waters presumably carried much sediment, the coarser part of which was deposited within a few miles of the ice edge. Outwash deposits laid down in valleys by glacial streams are called "valley trains"; deposits spread widely over level plains by sheet wash are called "outwash plains."
2. In many valleys there are remnants of glacial outwash which once covered the valley floor. Such remnants occur as terraces several feet above the floodplain of the stream, and in most cases they are distributed irregularly along the valley. See Figure 255, and the Ottawa (Ill.) topographic map [posted].
3. How would you expect terraces of the type described in the preceding question to compare in suitability for agriculture with floodplains in the same valley?
4. In a number of instances valley towns have been established on terraces in preference to floodplains. Account for this choice of town sites. Read "Terrace Towns of the Upper Mississippi" (pp. 237–239), and see Figure 258, and the Ottawa (Ill.), Waukon and Elklader (Ia.–Wis.), and Lancaster (Wis.–Ia.–Ill.) topographic maps [posted]. Note the location of river cities and villages shown on these maps.
5. Would you expect to find gravel pits (Fig. 257) in the terraces or in the floodplains of valleys of the type referred to in question 2? Why?
6. Not all river terraces are of glacial outwash. Many terraces are remnants of alluvial plains below which the river cut subsequent to their deposition. Alluvial terraces of this type are in most

instances of more fertile soil than terraces of glacial outwash. Why?

7. An excellent example of a widespread outwash plain is to be seen on the Three Rivers (Mich.–Ind.) topographic map [posted]. The northwestern part of the area covered by this sheet is rough moraine. To the east and south of the rough moraine is an outwash plain several miles wide. Cut into this plain are the shallow stream valleys of the St. Joseph and its tributaries. How would you expect the rough moraine area and the outwash plain shown on this map to differ in suitability for cultivation?
8. Many more plains of glacial outwash lie within the glaciated regions than at their borders (Fig. 254). This results from the fact that from the edges of later and more restricted ice sheets water carried material out on to areas which had been covered by older and more extensive ice sheets (Fig. 253).
9. What do you suppose are the chief uses to which the gravel excavated from the numerous pits in plains of glacial outwash in the United States are put?

LACUSTRINE PLAINS

1. A type of minor land form widely distributed over the earth, particularly in the middle latitudes, is illustrated in Figures 259 and 261. What is the most striking topographic characteristic of the area shown in the photograph? Suggest possible natural handicaps to agriculture on plains of the type illustrated.
2. The area shown in Figure 259 is part of an extensive lacustrine plain. Its low relief is believed to be due to the fact that in the recent geologic past (perhaps ten thousand years ago) it was the floor of a lake (Fig. 261), hence the name "lacustrine plain." This "Lake Agassiz Plain" constitutes a considerable part of the fertile prairie plains of Minnesota, North Dakota, Manitoba, and Saskatchewan. Some of the evidences that it is the bottom of a former lake are (*a*) its flatness, (*b*) shore features, such as beach ridges, dunes, and wave-cut cliffs, occurring more or less continuously along the supposed former lake border, and (*c*) an outlet valley without a stream. See Figure 262, and the Herman (Minn.) topographic map [posted]. Suggest the reason for the disappearance of Lake Agassiz. Why does the sediment washed into a lake tend to make the bottom smooth?
3. A part of this lacustrine plain and some typical country to the east of it are shown on the Herman quadrangle and in Figure 262. What physical differences between the two areas might have a bearing on the use of the land?
4. Parts of the Lake Agassiz plain are not suitable for cultivation because of poor drainage. This is a common condition on lacustrine plains. Why?
5. The soils of certain areas on lacustrine plains are likely to be unproductive. These areas are of three types: (*a*) flat sandy stretches at the general level of the plain, (*b*) sand and gravel ridges a few feet high, (*c*) irregular hills from a score to a hundred or more feet high. The flat, sandy areas probably are where currents in the ancient lakes spread sand or fine gravel over the bottom. The low ridges of sand or gravel (shown on the Herman map and in Figure 262, where they are marked "Norcross Beach" and "Herman Beach") probably were developed by waves and currents as bars in the lakes, or by waves as beach ridges at the edges of the lakes. The sandhill areas common along the borders of lacustrine plains are dunes, similar to those developed along the seaward edges of coastal plains of unconsolidated marine sediments.

6. What are the two major difficulties in making good roads on lacustrine plains? Suggest the reason for the location of the diagonal roads shown on the Herman topographic map.
7. Lacustrine plains similar to the Lake Agassiz Plain are numerous within and bordering the glaciated areas shown in Figure 240. These plains are much alike in land forms, but as might be expected, their soils vary widely in fertility and their area in most cases is much smaller than that of the Agassiz Plain. The lacustrine plains about the borders of the lower Great Lakes (Fig. 263), were formed under glacial extensions of the Great Lakes. The northern part of the Findlay (Ohio) topographic map [posted] shows part of the lacustrine plain south of the western end of Lake Erie.
8. Many relatively small lacustrine plains of a type rather different from that considered in the preceding questions are to be found within the glaciated areas of North America and Europe. They are the result of the disappearance of small lakes or ponds similar to those now found in depressions in moraine plains. Many such lakes and ponds are being converted into lacustrine plains at the present time; some by being slowly filled with sediment washed into them, some by the accumulation of remains of bog vegetation, which grows in their waters, some by being tapped and drained by streams or by ditches or lines of tiling. The soils of such plains are likely to be peaty; if so, they are in most cases of no great agricultural value.
9. Still another type of lacustrine plain is shown in Figure 264. These plains, of which there are numerous examples in desert regions, are the floors of extinct lakes that disappeared with a change of climate in the region. What sort of climatic change would cause the shrinking and perhaps the final disappearance of a lake? The soils of such lacustrine plains may be unsuited to cultivation, even if water is available for irrigation, because of their high content of various salts inimical to crops. Can you account for this high salt content?

PLAINS HAVING RESIDUAL SOILS

1. The minor land forms thus far studied (excepting ice-scoured country) have been built up by importation and deposition of materials through the agency of water, wind, or ice. In contrast, the land forms of many regions represent the result of disintegration of the bedrock, some of which remains as soil.
2. Examine the Lancaster and Lebanon (Pa.), the Charlotte (N.C.–S.C.), the Georgetown (Ky.), and the Murfreesboro (Tenn.) topographic maps, and Figures 265, 267, and 268. The areas represented all are dominantly agricultural, although the land forms and soils are quite different from those which characterize flooded alluvial plains, well-drained alluvial plains, or piedmont alluvial plains. What differences in land forms appear from a comparison of the topographic maps of these several types of plains? Would you expect to find a corresponding difference in the distribution of cultivated land?
3. Soils on plains of the type represented on the topographic maps listed in the preceding question vary widely from place to place. They may be thick or thin, stony, sandy, silty, or clayey in texture, and hopelessly sterile or perennially fertile in quality. The Kentucky Bluegrass (Georgetown map and Figs. 268 and 232), the Nashville Basin (Murfreesboro map), and the Lancaster District (Lancaster map and Figs. 265 and 266) are famous for high crop yields. Lancaster County has been producing wheat since 1700, and today averages as many bushels per acre as any county in the United States. The Bluegrass soils are very fertile; re-read the description of this area on pages 204–208. The district known as the Knobs, surrounding the Bluegrass and the Highland Rim of the Nashville Basin have low crop yields. The Piedmont (Charlotte map and Figure 232) is characterized by alternate bands of fertile and infertile soil, depending upon whether it is sandy or silty. In some areas of residual soils rock outcrops in many places and the land is of little agricultural value (Fig. 269).
4. The areas referred to in the preceding questions are plains having "residual" soils. Such areas, in contrast to the minor land forms previously considered (the surfaces and soils of which have resulted from deposition of materials brought to their present location and deposited there by streams, lakes, seas, glaciers, or the wind), possess (*a*) surfaces developed by the erosional action of streams

wearing the land down, and (*b*) soils developed by long continued weathering of the upper layers of the bedrock into a mantle of unconsolidated residual material. Read "The Agents and Processes Involved in Weathering" (p. 239).

5. Why do the soils of plains having residual soils vary widely from place to place (*a*) in fertility, and (*b*) in thickness?
6. Why do plains having residual soils differ considerably (*a*) in relief, (*b*) in the proportion of gentle slopes to fairly steep slopes, (*c*) in productivity, and (*d*) in percentage of cultivable land. Note the differences shown on the topographic maps posted.
7. Cultivation of certain areas on plains having residual soils is likely to be attended with the difficulty illustrated in Figure 270. What is a better use for such areas than cultivation?

SOILS

1. Are areas within which soils are uniform likely to be larger or smaller than climatic regions? Than land-form regions?
2. What is the agricultural significance of each of the following points: (*a*) for the surface soil, its thickness, its mineral composition, the size of its particles, and its humus content; (*b*) for the subsoil, the size of its particles, the degree of its compactness; (*c*) the depth of bedrock beneath the surface? Read "Soil Conditions Favorable for the Growth of Agricultural Plants" (pp. 239–242).
3. Soils vary widely in the characteristics discussed in the preceding question. These variations result from the facts (*a*) that soils are made of different kinds of materials, and (*b*) that they are formed by different agents or processes. Read "Types of Soils" (pp. 242–251).
4. Are sand dunes in humid regions and sandy soils in deserts unproductive for the same reason?
5. What are the outstanding characteristics of the predominant soils in each of the following types of climate: (*a*) rainy low latitude climate, (*b*) middle latitude desert, (*c*) humid continental climate with a natural vegetation of prairie grasses, and (*d*) humid continental climate with a natural vegetation of forest (Fig. 271).
6. Make diagrammatic maps showing the range in size and the distribution of the soil particles on (*a*) a piedmont alluvial plain, (*b*) a terraced valley train of glacial outwash, (*c*) a large lacustrine plain, (*d*) a coastal plain of unconsolidated marine sediments, (*e*) a moraine plain.
7. In humid regions the roots of most annual crop-plants, such as wheat, penetrate only the surface soil, and therefore draw little or no nutriment directly from the subsoil; the roots of most perennial crop-plants, such as fruit trees, penetrate deeply into the subsoil, from which they draw most of their nutriment. In the case of shallow-rooted plants, moisture conditions in the surface soil are related to the character of the subsoil.
8. In certain places in deserts many plants send out deep roots. Why? In most places in deserts, however, most plants have shallow, widespreading roots. Why? Do you suppose that these contrasted root habits are the result primarily of chemical composition of soils, size of soil particles, or soil moisture conditions?

EARTHQUAKES AND VOLCANIC ERUPTIONS

1. Destructive earthquakes are relatively rare in most parts of the earth. In fact, over a large fraction of the earth's surface, destructive earthquakes are unknown. In certain regions, however, earth tremors of sufficient violence to do damage to buildings occur every few years, or at least every one or two generations (Fig. 274). In some cases the damage done by earthquakes is enormous. The greatest catastrophes occur when violent earthquakes shake areas of dense population, particularly cities (Figs. 272–276). Recall disastrous earthquakes of which you have heard and locate the places on the relief maps in the atlas and on the map, Figure 274.
2. A common accompaniment of an earthquake is fire. Why? Read "The Destructiveness of Earthquakes" (pp. 251–254).
3. Volcanic outbursts constitute another violent earth phenomenon that may cause much damage to man and his works. The materials ejected may be molten lava, solid rocks, volcanic dust (pumice), or gas. Many volcanic eruptions occur in unsettled or sparsely settled regions and thus do little or no damage. Some volcanic areas, however, are rather densely populated. People may settle very close to a volcano which, after decades or centuries of quiescence, suddenly breaks out in eruption (Figs. 277 and 278). Read "The Destructiveness of Volcanoes" (pp. 254–261).
4. Why do people persist in returning to regions subject to devastation by earthquakes or volcanic eruptions? For example, in the area shown in Figure 278, a volcanic outburst in 1914 buried terraced fields under 2 or 3 feet of sterile ash and stones. Within a few months, however, the farmers of this district had returned and were hard at the laborious task of removing these volcanic ejecta from their fields.

REVIEW OF MINOR LAND FORMS

1. For each of the minor land forms state the typical character and distribution of each of the following elements of the natural environment and of economic life. Arrange your statements in the form of a table.
   a) Surface.
   b) Streams and lakes.
   c) Soil.
   d) Natural vegetation.
   e) Cultivated land.
   f) Density of population.
   g) Farmsteads.
   h) Cities.
   i) Roads.
   j) Railroads.

CHAPTER IV

BEDROCK AND MINERAL DEPOSITS

BEDROCK AS AN ELEMENT OF THE NATURAL ENVIRONMENT

1. Think of all the ways you can in which the composition of solid rock and its distance beneath the surface of the ground have a bearing on (*a*) digging cellars, (*b*) excavating canals, (*c*) constructing subways, (*d*) obtaining foundations for skyscrapers and other heavy buildings, and (*e*) building large dams. Read "Engineering Problems as Related to the Depth of Bedrock (p. 261).
2. What are the common uses of rock? See Figures 279 and 280.
3. What characteristics must good building stone possess?
4. With the points of question 3 in mind, consider the utility of each of the following: granite, sandstone, limestone, slate, marble, shale. Read "Building Stone" (p. 262). Examine samples on display.[1]
5. In many places brick and tile have very largely superseded stone as building material. Suggest reasons for such a change. Read "Mineral Building Materials Other Than Stone" (p. 263).
6. What are the advantages of concrete as building material, over stone and brick? What materials are used in concrete?
7. What would you conclude as to the character of the region surrounding each of the following places where public buildings, and foundations and trimming of houses are largely of the materials noted: (*a*) Woodstock, Illinois: bowlders; (*b*) Joliet, Illinois: limestone; (*c*) Zanesville, Ohio: brick; (*d*) Aberdeen, Scotland: granite?
8. What largely determines whether crushed stone or gravel is used for concrete and road macadam in a given locality?

[1] Specimens of rock can be obtained from supply houses such as Ward's Natural Science Establishment, 84 College Avenue, Rochester, New York.

MINERAL DEPOSITS

1. Mineral deposits have been the first resource to attract large numbers of people into not a few regions. Cite several examples. In other cases long-settled regions have experienced a boom and a large influx of population as a result of the exploitation of mineral deposits formerly unworked (Fig. 281).
2. In some instances of the sort referred to in question 1, other economic pursuits presently have outstripped mining, and population has continued to increase. In some other instances, there has been a decline in population with the exhaustion of the mineral deposits. Why have different regions had such different economic histories? Read "Minerals and Population Movements" (pp. 263–266).
3. Iron, coal, copper, and petroleum sometimes have been called the four minerals most fundamentally important in the modern economic life of the Western nations. Defend or refute this contention. See tables on pages 275 and 276.
4. Of the many rich coal fields and iron deposits in the world, only a few are worked to any extent (Figs. 282 and 283, and the table on page 275). A large but little-worked coal field in Shansi Province, China, and a large but little-worked iron deposit in the state of Minas Geraes, Brazil, are examples. Account for such non-utilization. Read "Economic Aspects of Minerals" (pp. 267–270).
5. What relation between coal deposits and cities is suggested by Figure 284?
6. Of what significance is each of the following conditions likely to be in determining the desirability of working any particular mineral deposit?
   a) Depth of the deposit below the surface of the ground (Figs. 285, 286, 288–294).
   b) Size of the deposit.
   c) Character of deposit—whether placer, stratum, vein, or other type (Figs. 292, 289, 291, and 294).
   d) Richness and purity of the deposit.
   e) Abundance of ground water.
   f) Character of the overlying rock, especially the immediate roof of the deposit in the case of a mine.
   g) Attitude or structure of the rock strata (Figs. 289 and 366).
   h) Distance and character of routes to regions where the mineral may be used (Figs. 287 and 339).

i) Economic possibilities other than mining in the region in which the deposit occurs.

j) Location and character of competing deposits.

7. The salt used by the natives of the Congo Basin comes mainly from the Sahara. Salt is high-priced in the Congo, but in the Sahara it is worth very little. What environmental conditions are responsible for these contrasts?
8. Why is it difficult to estimate the world-reserves of any given mineral? Why is it difficult to estimate the length of time such reserves will last?
9. Why does the problem of assuring an adequate supply of a given mineral for future generations differ greatly with different minerals? Read "The Conservation of Mineral Resources" (pp. 270–271).
10. What are the outstanding characteristics of life in mining districts? Read "Virginia City, a Mining Camp" (pp. 271–274).
11. Practically all mineral deposits become worked out after a few generations of exploitation. Hence, economic development based on mining is ephemeral. Contrast the future of the two areas shown in Figures 288 and 290.
12. In what respects is the exploitation of a petroleum field or a gas field quite different from that of any other mineral resource? See Figures 293 and 294.

CHAPTER V

GROUND AND SURFACE WATERS OF THE LANDS

GROUND WATER AND ITS USES

1. What is the source of the water in wells?
2. Why must wells be dug much deeper at some places than at others? Do you suppose one can dig anywhere and strike water?
3. Why does the depth at which ground water is to be found differ at different places? See Figure 295.
4. Why does the depth of water in wells vary from season to season?
5. It is said that in most parts of the eastern half of the United States, wells dug during the pioneer period had to be deepened after the forests were cleared and the land was under cultivation. Suggest reasons for this fact.
6. For what purpose are wells most commonly used in humid regions? What additional uses are made of well water in arid and semi-arid regions?
7. Which well in Figure 296 probably is safe for domestic use and which probably is not safe? Why?
8. In arid regions, where streams from mountain areas "dry up" on the plains, shallow wells dug some miles beyond the ends of the streams may strike water. What undoubtedly is the source of the water thus obtained? Does all the water in the streams sink into the ground?
9. Water is obtained not only from dug wells, all of which are relatively shallow, but also from drilled wells, some of which are hundreds of feet deep. From certain of these wells water flows out at the surface. The cross-section (Fig. 297) illustrates conditions which give rise to such a well. From a study of the diagram state the conditions requisite to a flowing well.
10. In some districts flowing artesian wells yield less water than formerly. "The Artesian Water Supply of Eastern South Dakota" (pp. 277–278) suggests reasons for such decreased flow, undesirable consequences of a decrease, and means of remedying the situation.

11. What are the advantages of artesian wells over ordinary wells?
12. Figures 298–300 illustrate some common situations for springs. Explain why there are springs in these situations.
13. Most springs vary considerably in their flow from season to season. Why?
14. Why does the water from some springs and wells taste of iron, sulphur, or other minerals?
15. Read "Springs" (pp. 278–280) on the varying occurrence and utility of springs in different regions.
16. Trace the course of water that soaks into the ground on the hilltop in Figure 295, and eventually gets into the lake. Most lakes and streams receive a considerable part of their water not only from run-off but from ground water. Explain.
17. Is the ground water probably scanty or abundant in each of the regions illustrated in Figures 222, 231, 234, 243, 246, and 265? Read "Types of Ground Water Occurrence" (pp. 280–284) and see Figure 301.
18. In what ways are the depth of the ground water surface and its fluctuation from time to time of significance in the cases noted below?
    a) Crops on low-lying ground in rolling moraine country.
    b) Unimproved roads on lacustrine plains.
    c) The amount of irrigation water necessary for deep-rooted crops like alfalfa on sandy valley terraces in the arid western sections of the United States.
    d) The availability of marshes in the glaciated sections of the United States for grazing and as a source of marsh hay.

STREAMS AND LAKES AS SOURCES OF CITY WATER SUPPLY

1. Nearly every city and large town derives its water supply from streams and lakes rather than from wells. Why?
2. In what ways may streams and lakes be unsatisfactory as sources of city water supply? Read "Surface Waters as Sources of City Water Supply" (pp. 284–289), which describes the measures taken by several cities to obtain a satisfactory water supply. Examine Figures 302–305, and the largest-scale relief maps available in your atlas.

STREAMS FOR IRRIGATION

1. Most streams in arid regions are of much greater value for irrigation than for navigation. Why?
2. On the density-of-population map of Africa note the density of population (1) along the Lower Nile and (2) on lands a few miles back from the stream. What is the reason for this contrast?
3. Why is the strip of dense population so narrow?
4. More land is irrigated in the Nile Valley now than formerly. What has made this possible? See Figure 310, and read "The Extension of Irrigation in the Nile Valley" (pp. 289–290).
5. Many fields in the Nile Valley raise two or more crops a year. In most irrigated districts of Western United States one crop a year is the rule. Can you account for this difference?
6. Look up the Tigris-Euphrates Lowlands on an atlas map. In what respects is this area like Egypt? History shows that the prosperity of the dwellers on the plain below Bagdad has depended largely on the good will of the people along the upper courses of the rivers. Why should this be so?
7. Where in India are most of the irrigated areas, as shown in Figure 306? What natural environmental conditions are responsible in large part for this distribution?
8. Most of the canal irrigation in India is dependent on diversion dams rather than on storage reservoirs. See Figures 308 and 309. If presently reservoirs are built in the mountains, what will be the effect on the area that can be irrigated?
9. Much irrigation in India and in other countries depends on wells rather than on streams. See Figures 80 and 307. Why do you suppose irrigation from wells was developed at a much earlier period than irrigation from reservoirs?
10. Where in the United States are most of the irrigated districts, as shown in Figure 142 and why?
11. Much of the irrigable area in Western United States remained undeveloped until the federal government took a hand. Why? Read "Irrigation in the Utah Oasis" (pp. 290–292), and see Figs. 230, 314 and 312.
12. How does the area of irrigated land in the United States compare with the area of unirrigated cultivated land? See table "Total Land Area, Improved Land in Farms, and Irrigated Land, for Each of the States of the United States" (pp. 293–294). Do you think a similar ratio would hold for the world as a whole? Why?

13. How are the facts shown in Figures 169 and 312 related to irrigation in Western United States?
14. Why is much irrigable land still unirrigated? See table "Irrigated and Irrigable Land in the United States, 1919 and 1920" (p. 294).
15. Can a large or a small percentage of the arid and semi-arid regions of Western United States be irrigated eventually? Why? Do you suppose your answer would hold true for the dry lands of the whole earth? Note in the table, "Arable Land of the Earth" (p. 168), the fraction of the total land area of the earth that is arid or semi-arid. On the world-map, "Climatic Regions of the Continents" (Fig. 1), note the regions in which irrigation is necessary for tillage. Do you suppose it is extensively practiced in all these regions? Why?
16. Irrigation canals of the type shown in Figure 311 are being built on many irrigation projects. Such canals increase the area that can be irrigated. Why? Is it desirable to make all the canals of this type? Under what conditions are lined canals essential?
17. The following questions have to do with the Salt River Reclamation Project, and illustrate problems typical of irrigation. On the relief map of the United States and on Figure 312 look up the location of the Salt River Reclamation Project, the general plan of which is shown in Figure 313. In answering the following questions, use as a source of information the Phoenix, Maricopa, Gila Butte, Mesa, Camelsback, Fort McDowell, Desert Well, Sacaton, Roosevelt, and Florence (Arizona) topographic maps [posted], and read "The Salt River Valley Irrigation Project" (pp. 295–300).
    a) What type of climate has the region in which the Salt River Project is located? See Figures 1, 4, and 5.
    b) What is the approximate average density of population in the region? See Figure 8. How does the density of population of the Salt River Valley compare with that of the region as a whole?
    c) What relation have the facts just noted to the establishment of the Salt River Reclamation Project?
    d) The reservoir for the Salt River Project is some thirty miles upstream from the head of the nearest canals, which take off at the Granite Reefs Dam. See Figures 313 and 314 and the topographic maps posted. Why do you suppose the reservoir was not located nearer the canal heads?

e) Water from the reservoir reaches the diversion dams at the canal heads by way of the river rather than through a canal. Do you suppose this is an exceptional procedure in irrigation projects? Why?

f) What seems to have been the topography of the reservoir site before the construction of the dam? What was the advantage of this site for impounding water? See Figure 315. (Note that all the topographic maps do not have the same scale and contour interval.)

g) What is the approximate gradient (fall in feet per mile) of the Consolidated Canal, as shown on the maps? Why is a high gradient in an irrigation canal undesirable?

h) From what point on the river is the water taken which irrigates the southern part of Section 35, about five miles southeast of Phoenix? From what point on the river is the water taken which irrigates the northern part of Section 35? Why is not all of Section 35 irrigated from the same canal?

i) Why do you suppose so much of the land within three-fourths of a mile of the river is not irrigated?

j) Drainage has become necessary on some of the irrigated lands on this project. How do irrigated lands become waterlogged?

k) Careful regulation of the amount of water each farmer uses has increased the area that can be irrigated. How?

l) Some lands in the Salt River district were irrigated before the completion of the reservoir in 1911. Water was obtained by a diversion dam located on the plains. Why was it not possible to irrigate so large an area then as now?

m) How would you expect the "duty of water" on this project to differ from that on the Belle Fourche Project, in Western South Dakota, Fig. 312? Why?

n) What do the "Electric Power Line" and "Power Canal" shown on the Roosevelt sheet suggest as to a valuable "by-product" of many irrigation projects?

o) From what you know of the climate, relief, soil, and water resources of this area, what crops do you think are likely to be grown in the district?

18. Read "The Practice of Irrigation" (pp. 300–304). In this connection see Figures 306–318.

19. Suppose a bond house is asked to guarantee the bonds issued by a particular irrigation district, why should each of the following points be investigated by the engineers of the house?

a) Total flow or volume of the stream.
b) Variation in flow from season to season (Fig. 319).
c) Reservoir possibilities.
d) Location of land requiring irrigation with reference to the reservoir or diversion dam.
e) Duty of water in the region.
f) Return water, after some years.
g) Costs of the project.
h) Value of crops to be obtained.
i) Quality of the water, particularly salt content.

20. Why is irrigation sometimes practiced in regions which are not arid or semi-arid? Give examples. See Figures 80 and 120, and table "Irrigated and Irrigable Land in the United States, 1919 and 1920" (p. 294).
21. In all the cases discussed in this excerise, what is the ultimate source of the water drawn from streams or wells for irrigation?

STREAMS FOR WATER POWER

1. Are the power possibilities of mountain streams larger or smaller than those of streams of the same volume on lowland plains?
2. Do you suppose that all mountain regions have large water-power possibilities? Why?
3. Water-power projects on plains can generate large amounts of power only if the streams utilized have large flow, whereas in mountain regions relatively small streams may furnish large amounts of power. Why is this the fact? See Figures 320 and 323.
4. The power projects shown in Figures 321 and 322 are typical mountain-region projects, whereas that shown in Figure 323 is a typical plains-region project. What are the chief differences?
5. Which section of the United States, as shown by the table "Water Power Resources in the United States" (pp. 306–307), has the largest potential water power? Why is this the leading section?
6. Compare the distribution of population in the United States, as shown in Figure 8, with the distribution of potential water power. What bearing has this relationship on the utilization of much of this resource?
7. The single most important use to which the hydroelectric power of the western mountain district of the United States may be put is suggested in Figure 324. Why is this application likely to remain for many years more important in the West than generation of power for manufacturing?
8. What other uses may be made of the water power of this region?
9. Read "Power from Niagara Falls" (pp. 305–306), and see Figure 325. What conditions led to the utilization of its power possibilities?
10. Which section of the United States, apart from the western mountain regions, has the largest water-power resource?
11. In Southeastern United States, streams leaving the Piedmont (Fig. 232) and flowing on to the Coastal Plain drop some scores of feet in a long series of rapids. Much cotton-textile manufacturing makes use of the water power along this "fall line."
12. Read "The Water Power of the World" (pp. 307–313). Summarize the reasons why it is desirable to develop the water-power resources of the world.
13. In estimating the desirability of developing a given project, the following items should be considered:

a) Annual flow of the stream.
b) Seasonal variation of flow, *particularly the low-water flow.*
c) Fall obtainable at the power station.
d) Ice conditions in winter.
e) Distance the power must be transported from the power station to the place of use.
f) Probable demand for the power developed.

Explain the bearing of each of these points on the feasibility of power development.

14. In the case of streams used for water-power or irrigation, seasonal variations in flow are of great significance. What bearing on seasonal variations, in stream flow has each of the following?
a) The seasonal distribution of precipitation of the area tributary to the stream.
b) Melting snow.
c) Glaciers.
d) Forest cover.
e) The presence of lakes and marshes draining into the stream.

15. The deposition of sediment in the reservoir of a power project or an irrigation project is sometimes a serious matter. Why does this problem vary greatly on different streams?

RIVERS AS COMMERCIAL HIGHWAYS

1. Are most of the world's navigable rivers in mountain regions or on plains? Why?
2. Which is the largest navigable river system in North America?
3. The four major divisions of the Mississippi System—the Ohio, the Missouri, the Mississippi above St. Louis, and the Mississippi below St. Louis—are so different, as river highways of trade and travel, that they may well be considered separately.
4. What does the relief map of the United States indicate as to the gradient of the Ohio River?
5. What bearing has this gradient on the navigability of the river?
6. The chief hindrances to the navigation of the Ohio are low water during summer and autumn, and ice during the winter and early spring. Why is the water high at certain seasons and low at others?
7. High water on the Ohio at times becomes a flood. In what ways are these floods hindrances to navigation?
8. In what other ways are such floods undesirable? Read "Floods and Their Prevention" (pp. 313–315), which deals with floods on several rivers.
9. At strategic points for river trade on the Ohio commercial cities have grown up, three notable examples being Pittsburgh, Cincinnati, and Louisville. Each has an advantageous location: Pittsburgh lies at the confluence of two streams, Cincinnati on the outside of a great bend (not a river meander), and Louisville at a rapids. How does each of these locations stimulate city growth? Examine the largest scale relief and density-of-population maps in your atlas. Would you expect to find commercial cities at similar situations on other navigable rivers? Read "Strategic River Locations" (pp. 316–317).
10. Traffic on the Missouri River never was so heavy as on the Ohio. Suggest reasons for this fact.
11. Low water on the Missouri is more marked and lasts for a longer period than on the Ohio. Examine rainfall maps of the drainage basins of the two rivers, and suggest explanation for these facts.
12. In what respects is the location of Kansas City on its river similar to that of Cincinnati on its river? Examine the atlas relief map.
13. The Upper Mississippi is less irregular in flow from season to season than either the Ohio or the Missouri, largely because the many

small lakes and marshes of the moraine plains of the Upper Mississippi country help to regulate the flow of streams in that region. How do these regulators operate?

14. Traffic in grain and lumber on the Upper Mississippi formerly was very heavy. Why has it practically disappeared?
15. St. Paul developed at the head of navigation in the days of bustling river commerce. Would you expect to find cities on other rivers at corresponding situations?
16. Study the St. Paul, Minneapolis, Anoka, and White Bear (Minnesota) topographic maps [posted],[1] noting the falls of St. Anthony, the bluffs below the falls, and the terrace on which the early town of St. Paul developed (north of the word "River" on the map). Suggest why the city was not established farther upstream.
17. Why is St. Louis peculiarly well located to profit from river trade? Examine the relief map.
18. Traffic is carried throughout the year on the Lower Mississippi. Why is this stretch much better suited to navigation than the other three sections of the Mississippi System?
19. What is the peculiar commercial advantage of the location of New Orleans, as compared with that of the other river cities considered?
20. To which of the cities considered in the foregoing questions is river commerce still of paramount importance? Of secondary, but still considerable importance? Why?
21. The Mississippi System greatly facilitated the development of the interior lowlands of the United States up to about the time of the Civil War. See Figures 326 and 327. Since then these rivers have been much less used than formerly. Why?
22. The Yangtze and its tributaries are the chief routes of trade in Central China, a region with a population of one hundred million or more. Compare Figure 318 with Figure 326. Of what advantage for commerce is the location of Shanghai? Of Hankow? Of Ichang? Examine carefully the largest-scale relief map in your atlas.
23. Are these types of locations likely to give rise to commercial cities on other streams? Refer to your answers to questions 9, 17, and 19, and see Figures 329–331.

[1] There is an excellent relief model of the Minneapolis–St. Paul area, which should be compared with the topographic maps if it is available.

24. Why is seasonal fluctuation of the sort suggested by Figure 121 a hinderance to commerce? What causes such fluctuations?
25. Why do you suppose the Yangtze at present is relatively so much more important than the Mississippi as a river highway? Study maps showing density of population and railroads.
26. On a world-map compare the size of the Rhine with that of the Mississippi. In spite of the difference in size, more traffic is carried on the Rhine than on the Mississippi. See Figure 332. Governmental encouragement of water traffic has been very pronounced in Germany. Suggest other reasons for the greater present-day use of the Rhine and other European rivers than of American rivers.
27. The two cities most concerned in the trade of the Rhine are Rotterdam and Mannheim. What advantages of location does each possess? Study the atlas relief map carefully.
28. What proportion of the commerce of the Amazon Region do you suppose moves by river? Why?
29. Which world-map among your materials suggests the chief reason why the aggregate volume of commerce on the Amazon is much less than that on the Yangtze?
30. Is the Amazon likely to develop into a highway as much used as was the Mississippi in its banner days?
31. What advantages for river trade has the location of Pará? Of Manaos? Of Iquitos?
32. Look up the Volga River on an atlas map. What river towns in the United States does Kazan resemble in location? Suggest reasons why no large city corresponding in location to Calcutta, New Orleans, or Shanghai has developed on the Volga.
33. A number of rivers are used for the purpose shown in Figure 333, even when they are unnavigable for ordinary boats. In what parts of the earth would you expect to find streams used in this way? Why?
34. Compare the part played by navigable rivers in the economic life of the regions traversed by the Mississippi, the Yangtze, the Rhine, the Amazon, and the Volga.
35. In a number of places canals have been constructed to connect navigable rivers or lakes. Most of the canals built in the United States were projected to link the Mississippi and Great Lakes systems with each other and with the Atlantic Seaboard. See Figure 334.

36. Several canals were planned to connect the Great Lakes and Mississippi systems with the Atlantic Seaboard, but only one, the Erie Canal, was completed and successful. After consulting a relief map, suggest a reason for the failure of the other canals.
37. The Erie Canal was very important as a trade route for several years after its opening in 1825, and had a large influence on the development of New York City and Buffalo. Why was it so important? Why was it such a large factor in the growth of New York City and Buffalo? Read "The Erie Canal and the New York State Barge Canal" (pp. 317–319).
38. Several canals linking the Mississippi System with the Great Lakes were completed and operated for some years. One of these, the Illinois and Michigan Canal, greatly accelerated the growth of Chicago. How were physical conditions especially favorable for the building and operation of this canal? See Figures 335 and 336, and the Chicago, Calumet, Riverside, Desplaines, Joliet, Wilmington, Morris, Marseilles, Ottawa, and La Salle (Illinois) topographic maps [posted]. Note (*a*) the course of the canal across the plain from the South Branch of the Chicago River to the Desplaines Valley at Mount Forest; (*b*) its course through the Desplaines Valley to beyond Joliet; (*c*) its course across the Morris Plain to its entrance into the Illinois Valley, and (*d*) its course through the Illinois Valley to La Salle–Peru. Note that there are several locks along the canal between Lemont and La Salle (Fig. 336.) Why were locks necessary between Lemont and La Salle, but not between the Chicago River and Mount Forest? Read "The Illinois and Michigan Canal" (pp. 319–324).
39. Rivers and canals are much more used in Western and Central Europe than in the United States. Compare the map, Figure 337, with an atlas relief map, and read "River and Canal Navigation in Europe and the United States" (pp. 324–332).
40. Under what disadvantages do rivers and canals operate in competition with railroads?
41. Will it ever again be desirable to use rivers and canals in a large way in the United States? Which routes are most likely to be developed? Why? Read "The Decline and Revival of Commerce on the Inland Waterways of the United States" (pp. 332–334), and see Figure 338.

GREAT LAKES AND INLAND SEAS AS HIGHWAYS

1. In what respects are large lakes superior for navigation to large streams? In what ways are they inferior?
2. On the world-relief map and on the relief maps of the continents look up the following inland seas or lakes: Superior, Michigan, Huron, Erie, Ontario, Winnipeg, Great Slave, Titicaca, Caspian, Aral, Baikal, Victoria, Tanganyika. How do they compare in area? Do you suppose their commerce is proportional to their area?
3. Suggest reasons for the marked differences in the amount of commerce carried by these lakes and seas.
4. The Great Lakes are much more used than any of the other waters noted above. Why? What are the chief commodities carried on the Great Lakes, from what areas do they come, and to what areas do they go? See tables, "Principal Commodities Shipped on the Great Lakes," and "'Soo' Canal Traffic" (p. 335), and re-read so much of "The Decline and Revival of Commerce on the Inland Waterways of the United States" (pp. 332–334) as applies to this question.
5. What would seem to be the advantages of location as lake ports of Duluth, Chicago, and Buffalo? Does the table, "Shipments and Receipts of Freight at Principal United States Great Lakes Ports, 1916" (p. 336), indicate that these places are ports of major rank?
6. Why have the Great Lakes not declined in importance as an inland waterway as the Mississippi has done? See Figures 339 and 326, and the table, "Freight Shipments on the Mississippi River System and on the Great Lakes, 1916" (p. 336).
7. The development of car ferries on the Great Lakes, by which trains are taken across in sections (e.g., between Milwaukee and Grand Haven), suggests the barrier to land transportation which large lakes or inland seas constitute. See Figure 340.
8. This barrier influence of the Great Lakes has been important in the development of Chicago as a railway center. Note on the railroad map (Fig. 196) the concentration of lines at the southern end of Lake Michigan, due in part to the swinging southward of lines in the latitudes of the lakes.

CHAPTER VI

OCEANS AND THEIR COASTS

On a population map of the world the oceans are vast empty spaces. Yet the geographic significance of these expanses of water, which cover about three-fourths of the earth's surface, is not wholly negative. The oceans are useful to man in a number of ways. Moreover, their usefulness varies from place to place. This fact suggests that it would be desirable to divide them into regions (as has been done in the case of land forms, for example), each region being differentiated from its neighbors on the basis of natural (physical) characteristics which have important bearing on human activities. Unfortunately, the data concerning the natural characteristics of oceans are so incomplete that regional subdivision is impossible at this juncture. In the following exercise an attempt is made to point out what these characteristics are, and to suggest their bearing on economic life.

Sea coasts belong to the lands as well as to the oceans, their natural (physical) characteristics being partly those of land forms and partly those of oceans. For this reason they can best be understood after both land forms and oceans have been studied.

THE OCEANS

1. In what ways are the oceans of economic importance?
2. What products are obtained from the oceans?
3. Suggest differences in physical conditions from place to place in the oceans, that may be responsible for the fact that some of these products come from one part of the ocean and others from other parts. Examine the atlas map of ocean currents and Figures 341–343, and read "Products of the Oceans" (pp. 337–338).
4. The oceans are much used as highways of trade. Why? From the standpoint of commerce should the oceans be thought of as separating or connecting the continents?
5. Do you imagine that more trade is carried on by sea or by land? Why should this be so?

6. Which nations are particularly interested in the oceans as highways of trade? Read "Strategic Ocean Locations" (pp. 338–341).
7. Other conditions being favorable, vessels tend to follow the shortest sea-routes between ports. On Figure 363 (a world-map on the Mercator projection) lay a straight-edge or ruler so as to connect (*a*) Panama and Yokohama, (*b*) New York and Hamburg, and (*c*) Melbourne and Cape Town. On a globe stretch a string between these places. Compare the location of these actual shortest lines on the globe with the apparent shortest lines on the world-map. The shortest line on the surface of the earth connecting two points is part of the circumference of a circle which bisects the earth. Any such circle is called a "great circle," and a route traversing a part of its circumference is known as a "great circle route." What great circles are shown on the ordinary globe? Very few great circle routes show as straight lines when plotted on most world-maps. Why?
8. Note cases where ships deviate from Great Circle routes because of one or another of the following reasons.
   a) Intervening land areas, as on the route from Seattle to Yokohama. Refer to a globe.
   b) Fog and iceberg infested waters, as on the route from Liverpool to Boston. See Figures 344 and 346, and read "The Ice Patrol along Steamship Routes in the North Atlantic" (pp. 342–346).
   c) Winds, as in the case of sailing vessels bound from Northwestern Europe to the west coast of South America (Fig. 347).
9. Why cannot the captain of a ship rely solely on the compass to determine the course his vessel is following and its location on that course?
10. What additional information does the "ship's log" give him? Can he navigate his ship safely with compass and log? See Figure 345.
11. By determining latitude and longitude the captain can find out his exact position, even when out of sight of land. Read "Latitude and Longitude Determination on Shipboard" (pp. 346–347), and see Figures 348–350.
12. Suppose the navigation officer on a steamer takes the following readings at noon of June 21: (*a*) Greenwich time, as shown by the chronometer, 6:40 P.M.; (*b*) elevation of the sun, as shown by the sextant, 57°; (*c*) direction of the sun, N. Locate the ship on a world-map.

13. Suppose the officer of the ship referred to in the preceding question wishes to lay a course for the Panama Canal, for what ocean current and what winds must he make allowance? See atlas map of ocean currents, and Figure 347.
14. On the journey between New York and Hamburg the hands of a ship's clock are set ahead or moved back each day. Are the hands set forward or backward on the eastbound voyage? Why? The number of minutes the hands are moved each day depends on the distance traveled by the ship in the preceding twenty-four hours. Why? See Figures 350 and 351.
15. Passengers on trans-Pacific steamers are likely to be perplexed at "losing" or "gaining" a day when the International Date Line is crossed. See Figure 351 and be prepared to explain why the day is gained or lost. The International Date Line has been established by agreement among the nations. Why do you suppose it was located where it is? Why does it not coincide exactly with a meridian of longitude?
16. The following is an abridgment of a sea story which appeared in the New York papers:

    Five hundred and nineteen days the sailing vessel *Garthway* took to battle her way around the globe from Grangemouth, Scotland, with a cargo of briquet coal for Iquique, Chile. The ship was delayed by headwinds and calms, and finally lost her fore and main topmasts and jib-boom in a Pampero off the River Plata. After several attempts to weather Cape Horn she was compelled to sail [eastward] around the world, going to the south of Australia, to get to the coast of Chile.

    a) Where may calms have delayed the vessel? See Figure 347.
    b) What winds did the ship encounter in trying to round Cape Horn?
    c) What is a "pampero" like? See page 144.
    d) On the route finally followed from Cape Horn to Iquique, where might the ship have stopped for water and provisions?
    e) Do you suppose the cargo carried by the vessel is a common item of trade from the port whence it sailed?
17. Are the oceans more or less effective as separators of countries today than they were one hundred years ago? Why?

COAST LINES AND HARBORS

1. In connection with what economic activity is the character of the coast of a region of chief importance? Is the whole coast line of equal importance to this industry?
2. What qualities do you believe a first-class harbor must possess?
3. Harbors may be classified into several types on the basis of physical characteristics which result from the geologic history of the coastline. Examples of the major types are the following:
   a) Unsubmerged river-mouth harbor—New Orleans. See the topographic maps of the Mississippi Delta listed on page 56 [posted], and Figures 219 and 329.
   b) Submerged river-mouth harbor—Baltimore and New York City. For Baltimore, see the Gunpowder, Baltimore, North Point, and Relay (Maryland) topographic maps [posted]. For New York, see the New York and Vicinity (New Jersey–New York) topographic map [posted], and Figure 352.
   c) Fiord harbor—Prince Rupert. See Figures 354 and 355.
   d) Island protected harbor—Boston. See the Boston and Vicinity topographic map [posted], and Figure 353.
   e) Lagoon harbor—Galveston. See Figure 362.
   f) Spit harbor—Provincetown. See the Provincetown and Wellfleet (Massachusetts) topographic maps [posted].
   g) No harbor—Iquique. See Figures 357 and 358. In such cases advantage is taken of some slight irregularity in the coastline.
   h) Artificial harbor—Madras. See Figures 359–361.
4. Rate each harbor listed in the preceding question according to the following qualifications: (*a*) shelter from storm winds and waves; (*b*) depth (the larger ocean vessels draw 35–40 feet of water and anchor chains are about 300 feet long); (*c*) tidal variation, not only in the harbor, but also in the entrance channel; (*d*) depth and straightness of the entrance channel; (*e*) suitability of the shore for wharves and a town. Read "The Environmental Background of Ports" (pp. 347–355).
5. What influence has the increasing size of ships had on the number of harbors that can take care of ocean traffic? Harbors on what types of coast do you suppose have been particularly affected by this change?
6. In each type of harbor what sorts of improvements have port authorities had to make to keep pace with the growing need of deeper water for larger ships?

7. Does a large port necessarily develop on every first-class harbor?
8. Why have large ports developed at some places lacking good natural harbors?
9. Figure 356 shows a part of the wharves of a city located on the sea edge of an extensive desert. How can you account for the large volume of shipping evident in the photograph?
10. On an outline map of the world mark with a conspicuous red dot the location of each of the ports in the table, "Value in Millions of Dollars of the Foreign Commerce of the Principal Ports of the World" (pp. 355–356), which has a total foreign commerce of more than $500,000,000 a year. Show the location of the ports in the list with from $200,000,000 to $500,000,000 by blue dots, and those with less than $200,000,000 by smaller black dots. What does this map and appropriate large scale atlas maps suggest concerning the significance to a port of its tributary area?
11. How do emerged coasts in general compare with submerged (drowned) coasts in the number and quality of harbors? Why? Examine the largest-scale atlas maps available with a view to determining to which type of coast each of the following belongs: Greece, South Atlantic and Gulf coasts of United States and Mexico, New England and Eastern Canada, Pacific Coast of North America north from the Columbia River, east coast of Peninsular India, Tenasserim Coast, Brittany.
12. Approximately how often do high and low tides occur? What bearing do tides have on the time of departure and docking of vessels at many ports? Why? Read "Tides and Seaports" (pp. 356–358).

CHAPTER VII

SHAPE, SIZE, AND LOCATION AS ELEMENTS OF THE NATURAL ENVIRONMENT

1. Does an ordinary photograph give an accurate representation of the shape of a mountain, lake, or other feature of the earth's surface? See Figures 193 and 198. Does an airplane photograph or a bird's-eye view better represent shape? See Figure 353. What is the most common device for depicting the outline shapes of surface features of the earth?
2. Compare the shape of North America (including Greenland) on the following world-maps: (*a*) Goode's Homolosine (Fig. 364); (*b*) Mercator's (Fig. 363); (*c*) Mollweide's Homalographic (Fig. 365). Which most nearly corresponds to the shape of the continent as portrayed on the globe?
3. Is the shape of North America on the continental relief map in your atlas more or less accurate than on each of the world-maps examined? Compare the atlas map with the globe, and suggest why?
4. What is the relative area of the several continents, as shown on the world-maps mentioned in Question 2. Which of these maps is least trustworthy in determining the relative size of the continents? Give an illustration to prove your contention.
5. Does the map, Figure 98, give the correct impression of the distribution of wheat acreage?
6. In world regional comparisons it is highly desirable to use maps that show true relative size and true shapes of regions. Why?
7. A map projection is a scheme for representing on a flat surface the curved surface of the earth. Map projections have been devised to meet one or more of the requisites of an ideal map: (*a*) correct relative size of areas, (*b*) true shapes of areas, (*c*) representation of the shortest distance between places by straight lines, (*d*) use of straight lines for parallels of latitude. Why is it desirable that a map should possess these requisites? Why is it impossible to devise a projection that meets all these requisites? Examine maps and a globe in connection with each of the points just made.

8. Read "Map Projections" (pp. 359–361).
9. Examine various maps and note their *scale*. What is meant by the term *scale?* In what three ways is the scale of maps indicated? Just what do the following figures mean when used to indicate the scale of a map: 1/50,000 or 1/100,000?
10. Compare the scale used in the case of (*a*) atlas maps of continents, (*b*) atlas maps of countries, (*c*) wall maps of continents, (*d*) wall maps of countries, (*e*) most of the topographic maps issued by the United States government, (*f*) detailed city maps such as one commonly uses to find his way about a city? Why are the atlas maps of continents on such a small scale? Why are the atlas maps of countries on smaller scales than the wall maps of countries? What practical consideration largely determines the scale in cases (*a*), (*b*), (*c*), and (*d*)? Why must maps in city guides be on a large scale?
11. The location of a region with reference to other regions is a matter of fundamental importance in economic geography. It involves (*a*) distance, and (*b*) character of intervening areas, especially in their bearing on routes of trade and travel. Use a globe and appropriate maps to compare the location of The Pampas of Argentine and of the plains of Southwestern Siberia with reference to the British Isles, and suggest the bearing of distance and character of intervening areas on economic relationships.
12. By the use of sextant and chronometer, explorers in uncharted wildernesses can determine latitude and longitude so exactly that maps which they make en route can afterward be fitted accurately into maps of the whole country or continent of which the newly explored areas form a part. Large-scale maps of Africa, South America, and Asia show strips or patches of mapped country alternating with or surrounded by unmapped areas. Explain the necessity of latitude and longitude determination in this connection.
13. The time by which people regulate their affairs in civilized countries is not, at most places, true sun time, but rather the time of some meridian of longitude fixed by law or by common agreement (Fig. 351). Why have all parts of the United States not the same "standard time"? Why are there not more or fewer time zones in the United States? What in detail determines the location of the boundaries of the time zones?
14. What must the traveler journeying from New York to San Fran-

cisco do with his watch in order to keep time with the people in the cities through which he passes? See Figure 351.

15. How many time zones are there in the United States? Why do not their boundaries follow meridians? Approximately how many degrees of longitude does each cover? Why? Where is standard time synchronous with sun time?

PART II

TEXTUAL MATERIALS

TEXTUAL MATERIALS

CLASSIFICATION OF CLIMATES

The climates of the earth may be classified broadly into low latitude, middle latitude, and high latitude types: the first group characterized by continuously high temperature, the second by a marked seasonal rhythm in temperature, with a warm or hot season and a cool or cold season,[1] and the third by low temperature all or most of the year. In a very general way these groups of climates are marked off from one another by the Tropics of Cancer and Capricorn and by the two Polar Circles. The low latitude types, however, extend somewhat beyond the tropics, and the high latitude types somewhat overlap the polar circles. The consequent restriction of the middle latitude climates is of far-reaching geographic significance, since this group seems to be best suited to the development of the more progressive civilizations.

Within each of these three broad climatic groups there is marked variation from place to place in seasonal temperature, in the amount and seasonal distribution of rainfall, relative humidity, cloudiness, and fog, and in the direction and velocity of air currents.[2] Within the low latitudes the differences of paramount geographic significance have to do with moisture—particularly the variations from place to place in amount and seasonal distribution of precipitation; within the middle latitudes contrasts in temperature are as significant as those in precipitation; within the high latitudes differences in temperature are of primary importance. Thus climatic regions are differentiated on the basis of moisture or temperature or both.

Climatic regions are not all different from one another, however. In fact, there is marked similarity between certain widely separated regions, which permits classification into a few climatic types. These types are distributed more or less systematically over the continents,

[1] It is convenient to consider summers as *hot* if the average July or January temperature is 68° F. (20° C.) or above, and as *warm* but not hot if the July or January average is between 50° F. (10° C.) and 68° F. Winters may be thought of as *cold* if the average January or July temperature is 32° F. (0° C.) or below, and as *cool* but not cold if the January or July average is between 32° F. and 50° F.

[2] These items may be given the generic name, "elements of climate."

a fact which suggests an orderly and world-wide relationship among the climatic elements. Various classifications of climate have been attempted that take into account the factors underlying this systematic distribution of climatic types—such as latitude, altitude, distance from the ocean, direction and character of winds, and the character of the relief. The following classification, however, is based on the observed facts of climate (i.e., climatic elements) rather than on their supposed causes. The amount and seasonal distribution of temperature and precipitation are the principal facts used. Only those types of climate are distinguished that differ markedly from each other in their effects on man's economic activities and on human health and energy. The following types are indicated on the map (Fig. 1) "Climatic Regions of the Continents" (in the map pocket).

A. Low latitude types:
   1. Rainy low latitude type.
   2. Wet-and-dry low latitude type.
   3. Semi-arid low latitude type.
   4. Low latitude desert type.

B. Middle latitude types:
   5. The type occurring on west margins of continents in lower middle latitudes, or dry subtropical type.
   6. The type occurring on east margins of continents in lower middle latitudes, or humid subtropical type.
   7. The type occurring on west margins of continents in higher middle latitudes, or mild-winter–mild-summer type.
   8. Humid continental type with long summers.
   9. Humid continental type with short summers.
   10. The type occurring on east margins of continents in higher middle latitudes, or modified humid continental type.
   11. Middle latitude desert type.
   12. Semi-arid middle latitude type.

C. High latitude types:
   13. Lower high-latitude type.
   14. Subpolar or tundra type.
   15. Polar or ice-cap type.

D. Areas not clearly any of the preceding types, for the most part highlands or oceans, include a wide variety of climates and should not be thought of as constituting a single type of climate. These areas are unnumbered on the map.

It should be understood that each type of climate as mapped includes rather wide variations from the ideal type described in the

text; nevertheless, the regions included under any one type are similar in climate. Moreover, it should be understood that most climatic regions lack sharp boundaries; almost invariably there is gradation through transitional zones into adjoining regions. Therefore nearly all the boundary lines on the accompanying map are somewhat arbitrary.

Temperature and precipitation data for stations illustrating each type of climate are collected in the table "Comparative Climatic Data for Selected Stations" (pp. 190–191) and are presented in graphic form in Figures 11–46.

THE RAINY LOW LATITUDE TYPE OF CLIMATE

As is indicated in name, precipitation in this type of climate occurs throughout all or most of the year, although some seasons may be rainier than others. In most regions having this climate, convectional showers occur almost daily, so that afternoon engagements commonly are made for "after the shower." The downpour generally is heavy and frequently is accompanied by lightning and thunder, but it lasts only a few minutes. Relative humidity is high at all times.[1] Cloudiness is common, many places being cloudy much of the time.

The temperature is high throughout the year. Over most of the area the sun is nearly overhead at all seasons, and days and nights are about equal in length the year round. Freezing temperatures never have been recorded. Nevertheless, cloud, water vapor, and evaporation combine to prevent extremely high temperatures. The range of temperature lies between about 70° F. to about 90° F., the thermometer varying more from day to night than from season to season.

Winds are conspicuously absent in most regions which have this type of climate. An exception exists along some coasts of continents and on certain oceanic islands which lie relatively near the Tropics of Cancer or Capricorn. There steady easterly breezes, commonly called "Trade Winds," greatly diminish sensible temperature[2] night

[1] By *relative humidity* is meant the ratio between the amount of water vapor a given volume of air *does* contain and the amount of water vapor it *can* contain at the same temperature. This ratio is expressed in percentage.

[2] *Sensible temperature* refers to the degree of heat or cold felt by the human body. It is not recorded by the ordinary thermometer.

and day throughout the year. Throughout this type of climate thunder squalls occur from time to time.

Luxuriant forests of large trees, with a tangle of climbing vines, characterize this rainy, hot climate. No season of cold or drouth causes leaf fall, so that the trees, although broad-leaved, are evergreen. There is no definite season of flowering and fruiting, and a tree may carry blossoms and ripe fruit at the same time. Trees in this climate do not develop clearly defined growth rings, since growth is not interrupted by either a dry or a cold season. Therefore, the grain of wood from these trees is smooth and even.

Native animal life is largely of the flying or the climbing types, such as birds and monkeys, animals that are well adapted to getting their living from the forest fruits, which, for the most part, grow in the tree tops, where, in the light and sunshine, most of the trees and climbing vines put forth their flowers. Few animals dwell on the ground in the somber depths of the forest. The rivers, however, have a varied association of fish and other aquatic life.

Population is sparse in most rainy low latitude regions. The continuously hot and humid climate is enervating. The abundance of bacteria-carrying insect life makes certain diseases very common. The staple indigenous foods lack certain essential elements of a balanced diet, and so aggravate the health problem. Routes of travel and transportation must be hacked through the dense, vine-choked forests. The cost of construction and maintenance of railroads is great, and few lines have been built. Consequently, rivers are almost the only highways, and settlements are strung out along the streams. The interstream spaces are largely wilderness. Almost everywhere material civilization is at a low level and the natural resources are little developed. Native life is simple and primitive. A thatch provides shelter from the rain, fish and a few bananas, breadfruit, or coconut trees supply food, and few clothes are needed. Were the aborigines the only people interested in the rainy low latitudes most of these regions would be in a state of nature. Middle latitude peoples, however, greatly desire various products furnished chiefly by this climate—rubber, cacao, coconuts, bananas, certain cabinet and dye woods—and these commodities can be produced only by native labor. Therefore it has come about that European and North American trading companies have established plantations, the products of which are marketed in the middle latitude regions where they are in demand. Much of the colonial expansion of European

nations has resulted from such commercial enterprises. Europeans, such as plantation overseers, who try to live in the rainy low latitudes, find the climate so trying that frequent vacations in nearby highland areas or in the more distant middle latitudes are necessary.

SENSIBLE TEMPERATURE

"It feels colder than it is," or "It doesn't seem as hot as it is," are common expressions disclosing that many times the temperature of which we are sensible is not that indicated by the thermometer. In general, low temperature seems lower and high temperature higher when the air is moist, that is, when relative humidity is high. In the case of high temperature, evaporation from the surface of the skin is slight when the air is moist and considerable when the air is dry. Evaporation cools the surface from which it takes place; hence we feel less hot on a dry hot day than on a humid hot day. Were evaporation the controlling factor with low temperatures we should feel less cold on a humid cold day than on a dry cold one. The reverse, however, is the case, for humid cold seems colder than dry cold. The reason for this is that moist air is a better conductor of heat than dry air. Consequently, on a cold day when relative humidity is high, there is more active conduction of heat from the surface of the skin into the air than when relative humidity is low. This conduction of heat from the body lowers its temperature and makes us feel colder than when such conduction does not take place.

Sensible temperature has much to do with comfort, energy, and health. In the rainy low latitudes the high sensible temperature is uncomfortable and debilitating, if not actually unhealthful. In many desert regions, where the actual temperature runs very high, the sensible temperature is not disagreeable. During cold weather humid spells are more uncomfortable than dry periods. A whole category of words has come into use to express sensible temperature: thus certain warm days are referred to as *muggy*, *sticky*, *oppressive*, whereas cold weather often is described as *raw*, *chilly*, *penetrating*.

A DAY IN THE RAINY LOW LATITUDE TYPE OF CLIMATE[1]

The following description of a day on the Guinea Coast portrays the unpleasantness of this climate in places unaffected by steady winds.

"During the night the air has become cooled by a thunderstorm with a short but heavy downpour. The sun rises out of clouds which soon melt away under its rays. It is fresh and pleasant, with a few puffs of wind. Light white clouds spread fan-wise from the horizon and cross the valley, slowly changing form. Soon after sunrise the shaded thermometer rises to 80° F. The calm air gets hotter and hotter, and by 9 A.M. it is unpleasant to walk abroad, even with a sunshade. Reflection from the ground, wet from the night's storm, wearies the eyes, and combines with the heat, the high relative humidity, and the fever germs to make the sunshine dangerous.

"About 10 A.M. in spite of an increase of temperature of about 3° F., the heat is still bearable and admits of a little activity. The breeze is irregular and seems to be on the point of dying away at any moment. At midday the thermometer is still rising, and by 1 P.M. it stands at 86° F.; the sun is hidden at times as a few cumulus clouds traverse the sky; the wind is still very weak. By 4 P.M. the temperature is 88° F.; the sky is three-fourths clouded, and masses of clouds are piling up on the horizon. A dead calm supervenes. The heat now feels excessive, and though after 4 P.M. the thermometer rises not more than a degree, yet the heat seems to be increasing considerably; it is astonishing that so small a change has so profound an influence. The body starts with perspiration at the slightest exertion.

"At 6 P.M. the sun disappears into thick clouds, which it colours a brilliant copper. The temperature remains high. The calm continues except for a few puffs which bring no life and fail to reach the inside of the house. We are compelled to go outside or to ascend to the roof to try to get a breath from the faint stir of air. A little black cloud passes overhead, and a few drops of rain fall from it, but not enough to wet the ground.

"We go inside again, but the heat indoors is overwhelming and we long desperately for a breeze. The water, left in porous vessels to keep cool, seemed fresh in the morning, but now it is lukewarm, just as though it had been in an ordinary pitcher. There is no need

[1] A. Borius, *Climat du Senegal*. Quoted in Julius Hann, *Handbuch der Klimatologie*, II, pp. 52–53. Stuttgart, Engelhorn, 1910.

for a hygrometer to show that the air is saturated with moisture. It is this high humidity that makes the heat so overpowering, for the temperature is not excessive.

"Nothing can be compared with the feeling of utter prostration that overcomes a European. Though he sits motionless in an armchair he is bathed in perspiration as after violent exertion. Nevertheless his fatigue is not like that felt after work, but rather a weakness in the limbs, and especially in the bones—an indescribable feeling of discomfort which precludes all movement, all bodily or mental work, but yet prevents sleep. Clouds of mosquitoes swarm round him and he feels suffocated. These are the moments when the dreary passage of enforced idleness brings home to him the disgust and anguish of exile.

"By 10 P.M. the calm is palpable. The temperature continues high and fatigue intensifies discomfort. The head seems compressed in an iron band. Neither work nor reading is possible; either would require an effort of the will which we are incapable of making. Mental force is sapped even more than physical strength. Night drags on in this painful way unless a thunderstorm bursts, with heavy rain, in which case the temperature falls and the air takes on wholesome freshness."

THE LOW LATITUDE DESERT TYPE OF CLIMATE

At all seasons low latitude deserts have scanty rainfall, much sunshine, and little cloudiness. Daily and seasonal range of temperature is greater than in other low latitude climates. In all low latitude deserts the precipitation is too scant and too uncertain to be depended upon for tillage or grazing. In a few regions years may pass without any rain. In such places showers may occasionally be seen in the upper air, but the moisture almost always evaporates before reaching the ground. In most desert regions, however, there is some rain each year. It frequently falls in torrential showers, with rapid run-off from the bare ground. Dwellers in oases live in terror of these occasional rains, because loss of property and life is a common consequence of them. Relative humidity in deserts is low during the daytime, but the clear air and the exposed ground permit such rapid nocturnal radiation that dew frequently gathers. Light frost occurs

at times in the less hot season, although a night with frost may be followed by a day during which the thermometer reaches 70° or 80° F.

"Suddenly, almost without presaging twilight, the sun rises into the clear sky. In the dry atmosphere its rays are already scorching at this early hour, and, under the influence of reflection from stone and sand, the layer of air next the ground is heated rapidly. There is no active evaporation to moderate the temperature. After 9 A.M. the heat is intense and goes on increasing until three or four in the afternoon, when a quivering mirage may sometimes be seen, produced by the vibration of the air, warmed as in an oven. The heat slowly diminishes as night approaches. After suffusing the cloudless sky with momentary color, the sun drops out of sight. In the limpid night air rock and sand lose their heat into the deep blue of the sky, almost as rapidly as they acquired it. The reigning calmness of the atmosphere, which is so still that a flame burns without a tremor, still further favors the cooling of the air. People shiver, and it is not uncommon on winter mornings to find a film of ice on surface water."[1]

The natural vegetation of these desert regions is sparse, and consists of widely spaced plants with much bare ground between. Roots are likely to be more extensive than the parts above ground. Leaves are small or thick skinned or covered with hairs. These and many other characteristics of desert plants fit them to get along with little rainfall. After the rare showers the earth is carpeted with bright, ephemeral flowers.

Most animals in deserts have peculiar habits or characteristics that fit them for subsistence in these dry regions scantily covered with vegetation. Camels can travel far between drinks; lizards have small water requirements; burrowing animals avoid the dry atmosphere by remaining underground much of the day.

Approximately one-fifth of the fifty million square miles of the earth's land surface may be classed as desert, although by no means all of this lies within the low latitudes. The deserts altogether support several million people. Nevertheless, permanent population is practically lacking except in and about the oases, although nomadic tribes may wander at times into the desert margins. Oases may exist along streams or at springs, although all deserts possess water holes which do not support plants. The date palm is the characteristic tree of low latitude desert oases, and rice, cotton, wheat, millet, and numerous other crops are grown. Many small oases serve mainly as stopping

[1] Henri Schirmer, *Le Sahara*, p. 98. Paris: Hachette, 1893.

places on caravan routes across deserts. Some large oases are important sources of certain commercial products, such as dates, cotton, and wheat. All are densely settled, land holdings being small and land values high. Perhaps the most famous low latitude desert oasis is Egypt—the irrigated valley of the Nile. Extensive irrigated tracts recently developed in low latitude deserts are the Punjab in India and the Imperial Valley in the United States and Mexico. In contrast to these large irrigated districts, however, most low latitude oases consist of a few score or at most a few hundred irrigated acres.

WINDSTORMS IN A LOW LATITUDE DESERT[1]

Violent dust or sandstorms are not uncommon in deserts since there is little vegetation to hold the loose soil. Such storms may deal death to unsheltered caravans or dump barren soil on the carefully tilled oases. A diary of a Saharan journey in winter brings home these conditions.

"December 7 provided us with a 'gibli,' a strong south wind laden with sand, which nearly tore up our tent pegs and covered everything with a thick yellow coating. It was a most unpleasant day. Hair, eyes, and skin were full of sand. Everything we ate was flavoured with it. It oozed from the pillows and from every article of clothing. It penetrated every box and bag. The noise of flapping canvas and cracking pegs was a continual strain. All that day we sat inside the tent amidst blinding sand. It was in vain that we shut every curtain and flap. The whirling dust penetrated as if by magic. The only break in the monotony of removing continual layers of sand from faces and note-books was when a peg cracked under the strain and one side of the tent flew up with a scream of flapping canvas, tearing up half a dozen pegs with it. That night . . . . we all sat around a fire with a cold wind freezing our backs.

"The previous day the gibli had blown with a fairly high temperature at midday. This morning the wind had been in the east, swinging round to the north in the afternoon, yet the temperature at noon had been nearly as high as on the previous day. Desert weather seems to be quite illogical.

[1] Quoted, with omissions, from Rosita Forbes, *The Secret of the Sahara: Kufara*, pp. 60–189, copyright 1921 by George H. Doran Company, New York.

"December 15 provided us with few incidents. We did a dreary seven hours' riding with a cold south wind blowing straight in our faces. We wrapped our jerds and blankets round us.

"In a white starlight, clear and cold, with the rising south wind that is the bane of the desert, we laid our flea-bags on the lee side of the largest hillock and crept into them without undressing. We tried to put the flaps over our heads, but the sand, as usual, covered everything.

"We plodded slowly out of the hospitable town into a raging north-westerly wind. We meant to march on into the night and reach Buttafal about 10 P.M., but fate decided otherwise, for almost before the walls of Jalo had disappeared the wind strengthened into the worst gibli I have ever encountered. It was behind us, for we were heading south-east, yet the camels staggered and swung round, huddling against each other for shelter. I was nearly swept off the back of my blond beast. Every loose mat and blanket flapped in wide circles and loads began to sway dangerously. On all sides palms were bending and cracking in the sudden gale, while great leaves were torn off and whirled whistling above our heads. The air became a thick sheet of sand. Sun and direction were blotted out. Screaming gusts stung our faces and blinded us. It was the most extraordinary sight, for one minute camels and figures would be blotted out in a whirling white fog; then a head or a wildly gyrating blanket or a portion of a labouring camel would appear for an instant through the shroud and vanish again in the smarting dusk. We stumbled and choked and fell through the storm till even Abdullah saw it was useless. In an instant's lull a palm tree fence appeared to our left, with a small boy crouching beside a garden plot of onions, radishes, and pumpkins. We turned our camels toward the low shelter and they sank heavily to their knees beside a clump of the grey, nameless trees.

"The morning of January 3 was misty. Ripples of white fog blurred the landscape.

"The second night the desert had stuck in her claw again—fatal anaesthetic which makes one utterly careless of the future—'What matter dead yesterday and unborn tomorrow, so that the day be good?' In truth the days are generally extremely trying, for there is either a blazing sun which burns through the thin cotton [clothing], or a bitter wind which pierces every bone in one's body. Sometimes there were both together, and then one side of one is frozen and the other baked! One's skin split and blistered under this treatment,

but there was only one hour I shall never be able to forgive the desert. This was the moment when, at 5 A.M., one crept shivering out of one's warm flea-bag into pitch darkness, placed one's feet gingerly on icy cold sand, fumbled with numb fingers for a candle and matches, and proceeded to drag on cold, stiff garments from each of which fell a shower of sand. Meanwhile, with chattering teeth, one had to call out loud, cheerful greetings and hearty good wishes to rouse our improvident following, although one's mind contained nothing but venomous invective! However, the nights were good.

"January 14 produced about the most unpleasant specimen of desert climate. The sun, no doubt, was hot, but a cold, strong wind blew from the east, raising clouds of sand and making progress difficult."

THE COASTAL DESERT OF NORTHERN CHILE[1]

"The coast of northern Chile is quite the driest of which there is any record in the world. For a 21-year period Iquique has an average rainfall of [six tenths of an inch], and Arica (for a 19-year period) has still less [two hundredths of an inch.] But an average in the desert is as nearly useless a computation as even the desert affords. There is no such thing as a normal desert rainfall. Years of absolute drought pass, and the foreigner who comes out on a three-year or five-year contract may stay his time and depart without having known a drop of rain to fall; and he may even assert that it never falls and speak as one who knows because he 'has lived there.' The British Consul at Iquique told me that he had advised some of his friends who were coming out from England not to bring umbrellas, for in the fourteen years that he had then known the coast no rain had fallen. Yet on the night on which they disembarked from the steamer it was raining hard. In 1906 there was a three days' rain, a succession of light showers with intervals of heavy mist, which penetrated the houses and collected and ran off walls and ceilings and soaked the carpets and beds. It is only the rare downpour that gives Iquique anything at all to average through the years. It is as nearly like a rainless land as any that we know on the earth today."

[1] Isaiah Bowman, *Desert Trails of Atacama*, p. 40. New York: American Geographical Society, 1924.

THE WET-AND-DRY LOW LATITUDE TYPE OF CLIMATE[1]

This climate is like the rainy low latitude type in that it is characterized by relatively high temperature throughout the year. It is different, however, in that it has a marked seasonal alternation of rain and drouth and a considerable range of temperature from season to season. The rainy season lasts four to seven months, with moderate to abundant precipitation. The remaining months are quite or nearly rainless. The rainy period synchronizes roughly with the season of maximum heat. As the rainy season progresses, however, there is a notable decline in temperature; the hottest month, as a rule, just precedes the rains. The sensible temperature, in contrast, is likely to increase during the rainy season. In several regions having this climate, winds show marked variation with the seasons, and in the dry season they may be disagreeably laden with dust.

The natural vegetation in the wet-and-dry low latitude climate is deciduous forest, or grassland with open, parklike timber. The trees, which are broad-leaved, respond to the rhythm in rain and drouth by shedding their leaves in the dry season; the grasses wither during the drouth. Where the wet-and-dry climate grades into the semi-arid low latitude type tree growth is absent or consists of scrubby bushes. Where the population is sparse there is abundant animal and bird life.

Agriculture is highly developed in some regions of wet-and-dry climate, notably in India. In such places the crop system strikingly reflects the rhythm of the seasons. In India there are three groups of crops: (1) those raised in the rains, such as rice, cotton, and grain sorghum; (2) those raised in the dry season with or without irrigation, such as wheat and barley; and (3) those that grow throughout the year, such as sugar cane, depending on rainfall during the rainy season and on irrigation during the dry season. The length and the intensity of the rainy season vary from place to place within this climate, giving rise to wide variations in agricultural practice. It is helpful to think of this climate as having two subtypes or phases, a rainier and a less rainy, each characterized by its own crop combinations and methods of cultivation.

The wet-and-dry low latitude climate is much more livable than the rainy low latitude climate, for the dry and distinctly less hot season of the former gives a respite from the humid heat, whereas in

[1] This type of climate includes all except the drier phases of what is commonly called the "tropical monsoon climate."

the latter there is no break. Nevertheless, toward the end of the dry season in the wet-and-dry low latitude type, the temperature is likely to rise uncomfortably high, and the countryside may become very dusty. In the wet season a plague of insects adds to the uncomfortableness of life in unremitting humid heat.

THE SEMI-ARID LOW LATITUDE TYPE OF CLIMATE

This type of climate is characterized by a long dry season, and a very short season of rain. The seasonal range of temperature is about the same as that in the low latitude wet-and-dry climate, the coolest season coming when the sun's rays are most oblique, the hottest season occurring just before the rains. During the short season of rains, which is associated with the time of highest sun, the weather may be much like that of the rainy low latitudes. Throughout most of the year, however, dry and sunny days succeed one another without break, much as in low latitude deserts. During these months strong but variable winds are common, and the blowing dust becomes a plague.

Some regions possessing this type of climate present vast expanses of coarse grasses which grow to a height of several feet. In other regions the landscape is diversified by alternate patches of grass and clumps of scrubby, thorny trees or bushes with small leaves which offer little shade from the parching heat. The vegetation of both grassland (*savannas*) and thorn bush freshens and grows during the rains, and then withers and dries during the long season of drouth. This climate abounds in insects, the variety and prevalence of which makes living a torment that speedily ends in death for most animals not acclimated. On the other hand, it is the stronghold of a teeming native fauna. The abundant grass supports a multitude of herbivora whose slim long legs and keen ears and noses form their only protection against the lithe carnivora which stalk them at their water holes and along their trails. Myriads of birds live on the insects, the seeds of plants, and the carcasses of dead animals.

The population of these low latitude semi-arid regions is sparse and nomadic, and is engaged mostly in grazing cattle or "woolless" sheep. Tillage is little practiced because of the short season of scanty rain, but here and there are patches of millet or other quick-growing, drouth-resistant crops. The domestic animals of this and

other types of climate in the low latitudes generally are smaller than those of middle latitudes, and cows, sheep, and goats give less milk than the same breeds yield in the middle latitudes.

AGRICULTURAL PRACTICES IN INDIA

India is the one large area in the low latitudes with a dense population, and the relations between its economic life and the natural environment are therefore of peculiar interest.

Agriculture is the fundamental and dominant economic pursuit, nearly all of the three hundred million inhabitants of the country being engaged in tilling the soil. There is a marked seasonal rhythm in agricultural operations, for although the temperature is high all or nearly all year round there is a clearly defined alternation of rainy and dry seasons. Nevertheless, the kinds of crops grown and the ways in which they are grown differ notably in different sections of the country. These contrasted agricultural practices result primarily from differences in the length of the rainy season and in the abundance of rain. Secondary causes are (1) the differences from section to section in ground and surface water conditions, with consequent variation in irrigation possibilities; and (2) differences in drainage conditions.

On the Ganges Plain, from the Bay of Bengal northwest to the vicinity of Allahabad, the rainier phase of the wet-and-dry low latitude type of climate rules. The rainy season begins in April and continues until October. The average precipitation, varying from 60 to 70 inches near the sea to 35 or 40 inches at the inland end of the region, insures a plentiful water supply. This, coupled with high temperature, makes the region ideal for rice, which is the dominant crop. The fields are plowed and the young rice plants, previously started in small seed beds, are set out as the rains begin. As the rice grows, the fields, which are level and inclosed by low ridges, are kept flooded. On the Ganges-Brahmaputra Delta this water is supplied directly by rain and from the river floods, which overflow most of the land. Farther upstream (on the Middle Ganges Plain), where most of the alluvial lands lie above flood level, the rains are supplemented by water diverted from the stream through small canals and ditches. At the end of the rainy season the fields are drained, and the rice ripens and is harvested. Jute, which in contrast to rice is a cash

crop exported from the area, shares with rice some of the overflow lands of the Delta during the rains. During the dry season most of the land of the Delta lies idle. On the better drained lands upstream, however, dry season crops are common. These include wheat and barley, gram (a legume much like peas), and several oil seeds. None of these crops can stand the heavy rainfall and high relative humidity of the rainy season; hence they are planted at the close of one rainy period and harvested before the beginning of the next. They do, however, require some supplementary irrigation, which is provided mostly from wells. Sugar cane, which takes a year to mature, is planted on the Middle Ganges Plain at the beginning of the rainy season, and is irrigated during the following dry season, at the end of which it is harvested. Corn is a wet season crop of some importance.

The region of the Upper Ganges Plain and adjacent parts of the Punjab close to the Himalayas is characterized by the drier phase of the wet-and-dry low latitude climate. The season of rains extends only from June to September, and the amount of rainfall ranges from 35 or 40 inches in the southeast to 20 or 25 inches in the northwest. Owing to lack of water with which to flood the fields, rice is unimportant. The chief crops grown during the rains are several varieties of grain sorghums, a group of plants which yield well in hot regions of only moderate rainfall; other wet season crops are corn and cotton, the latter being largely exported from the region. The dry season is more important for farming than the season of rains. Wheat and barley, the principal crops of the region, serve not only as important food crops for home supply, but also as the chief export crops. Gram and oil seeds are lesser crops of the dry season. Much of the wheat and barley, and all of the other crops of this season, require some irrigation. Extensive irrigation systems have been built to utilize the water brought to this region by streams from the Himalayas.

The climate of the Sind and the western part of the Punjab is semi-arid to arid. By virtue of being traversed by the Indus River and its tributaries, this has become the chief region of irrigation agriculture in India. Extensive and complicated systems of canals, mostly in the Punjab, permit the cultivation of many thousands of acres which otherwise could not be tilled. Wheat, barley, gram, and oil seeds are grown in the months corresponding to the dry season of the Upper Ganges Plain. During the hot season, which corresponds to the season of rains of the Upper Ganges Plain, much less land is under cultivation, although some grain sorghum, corn, and cotton are grown.

The Deccan east of Bombay has a climate much like that of the Upper Ganges Plain, but its agricultural system is markedly different. This is due primarily to the lack of large perennial rivers for irrigation. Rainy season crops are in the majority. The drouth-resistant grain sorghums constitute the chief food crop. Cotton, of rather poor quality, is the main cash crop. In the dry season wheat, gram, and oil seeds are grown in considerable quantity, but they are likely to suffer severely if the rains of the preceding season have been unusually light. In fact, even the crops grown in the rains are likely to suffer from drouth. This is one of the chief famine regions of India.

The agriculture of the West Coast Region of Peninsular India contrasts most strikingly with that of the nearby Deccan. Heavy rainfall, of about the same duration and amount as that on the Ganges Delta, makes possible a large rice crop. Coconut palms fringe the shore, and on the hills a few miles inland rubber plantations are being established in clearings in the luxuriant natural forest.

Throughout India agriculture is intensive, because the population is dense. Yet the practice of growing two crops a year on the same field is rare, in spite of the demand for food and the suitability of the climate, because the soil, none too fertile at best, cannot stand the drain.

WEATHER CONDITIONS IN THE ZAMBEZI BASIN[1]

The following pages portray climatic conditions on the margin between the wet-and-dry low latitude climate and the semi-arid low latitude type.

"If you were to visit the regions bordering on the River Zambezi in the winter months of June and July, the climate would awaken an ardent desire in you to remain there for the remainder of your life. It is quite perfect. Warm, brilliant days, with a delicious touch of freshness increasing to an evening sharpness which necessitates flannels and a light overcoat.

"The winter months, or dry season, extend, with slight variation, from April to November. They are, as I have said, pleasant and

[1] Quoted, with slight omissions, from R. C. F. Maugham, *Zambezia*, pp. 383–388. London: Murray, 1910.

healthy in the extreme. Now the traveller and hunter of big game make their appearance; the deciduous trees are leafless; the grasses dry, yellow, and ready for the chance spark or deliberate act which, with the aid of a steady breeze, will turn vast expanses of golden grass-lands into so many hideous, bare deserts of heat-tremulous black. All nature seems to be at a standstill, hibernating. The rivers are low. Where, but a few short months since, wide, watery expanses rushed headlong towards the sea, their clay-colored waters swirling down in a relentless grip great islands of marsh grasses, village débris of various kinds telling of sudden freshets and quick disaster, great tree-trunks, and masses of undergrowth, there now remain but tranquil, placid channels, flowing smilingly at the bottom of steep, cliff-like banks. The morning grasses are heavy with great drops of dew, and dense, white fogs occur often, and frequently remain undispelled until nine or ten o'clock, provoking an astonishing amount of fluent profanity from the masters of the helpless river steamers. A very large proportion of the trees have now no leaves whatever; the grass-fires have devastated the face of the country, and left but the seared and blackened skeletons of grass-canes, of bushes, and shrubs. Beneath one's feet a raffle of fallen forest foliage, dry as so many chips, swirls about in the breeze, and the atmosphere, as though also seeking to assume a wintry aspect, becomes misty and opaque from the smoke of the numerous fires.

"With October the heat becomes very great. Vast belts of electrically charged, yellowish clouds, with cumulus, rounded extremities, begin to gather, and at the close of day are seen to be flickering in their murky centres with a menacing tremor of constant lightning. This may go on for a week or more, and then Nature arises like a strong man in his anger, and looses the long pent-up voice of the thunder and the irresistible torrents of the early rains. The first manifestation may come at evening, and is a soul-moving display of natural force.

"The day has probably been hotter than usual, and as night draws near the slight breeze of afternoon dies away completely. The air is positively sulphurous, and the smell of the soil is as the smell of sun-dried brick. Away to the southward, a lurid, yellowish grey bank of clouds may be seen mounting higher and higher towards the zenith. The higher it mounts, the faster it appears to travel, whilst the lightning, which plays ceaselessly through and through it, can be distinguished on the far horizon darting downwards in rosy, snaky, tremulous forks. Now, as the vast, luminous mass is almost over-

head, we see that the vaporous clouds of which it consists are swirling madly round and round, and as the first warm drop of rain falls with a splash on the stone verandah, a heavy, sullen peal of thunder echoes with long, hoarse reverberations, to die away in the distance as the storm bursts. White-robed servants fly about, bringing in chairs and hastily closing windows and doors. A gust of icy-cold wind is followed by another and another, and these fill the atmosphere with clouds of red dust, bending down the cocoanut palms. The [storm] is now at its height, and the rain, coming down in blinding sheets, in a few moments transforms the dusty red of the long sun-dried roads into rushing streams of dirty water. Now a close, warm smell of rain-damped earth rises from the grateful soil, whilst to a continuous, deafening cannonade of thunder is added an electric display so gorgeous that words seem powerless to convey an idea of the wonder of it.

"Fortunately these storms are short-lived, for the havoc they create is often serious.

"After such a disturbance as the one I have just described, rain is fairly continuous for some time, and the effect of this copious irrigation makes itself felt in every branch of animal and vegetable life. Within a few days the change is startling; the paths and roadways choke themselves with a rich clothing of newly sprung grasses, whilst the trees, the extremities of whose twigs and branches have been visibly swelling, now leap into leaf and blossom. The mosses, which for months past have looked like dry, bedraggled, colourless rags, regain once more their vivid, tender green. Now the forest throws off its puritanical greyness, and with an activity and rapidity beyond belief, decks itself in flowers of a thousand gorgeous shades of colour, from chrome-yellow and purple to grateful mauve.

"The birds now put on their finest feathers, the animals appear in their brightest hues. Colour and warmth run riot in the brilliantly clear air now washed clean from the mist and smoke which for so many months have obscured it. The clear verdant green of rapid-springing grasses and opening fronds clothes the landscape, and the distant peaks of the mountains lose their pale, bluey-grey haziness, and stand boldly out in the light of the sun. The months succeed each other, bringing with them new and strange beauties, for summer is now at its height, and trees and flowers at their most perfect period. Then, after a few weeks of heat and quiescence, comes the second phase. The rain, which about midsummer holds off for a time, now deluges the earth in tremendous downfalls, thunderstorms are frequent,

and floods occur. April comes, and suddenly Nature holds her hand. The swollen rivers and inundated plains shake themselves free from the redundant waters. The grasses have now reached a formidable height. The rains now cease, and the land begins to dry up. Rich greens turn to copper, and brown, and yellow, and little by little, with the advent of May, the winter returns with its sober greyness."

TROPICAL CYCLONES, TYPHOONS, AND HURRICANES

During the hotter months certain seas and coasts in the vicinity of the tropics are visited not infrequently by destructive storms, called variously "typhoons," "hurricanes," or "tropical cyclones."

"While most typhoons cause little or no loss of human life, occasionally the losses are appalling. The Swatow typhoon of August 3–4, 1922, caused the death of over 50,000 persons. The typhoon which struck Haifong, China, on October 8, 1881, was said to have caused the death of 300,000 persons. The two almost simultaneous typhoons of August 26–31, 1911, destroyed 44,000 houses in the southern part of Formosa, although only about 800 persons were killed or missing. The destruction due to typhoons is of four chief kinds: (1) The wind itself demolishes houses, breaks off trees, and sometimes blows boats upon the rocks. (2) Waves produced by the wind often engulf boats or break them or drive them upon the shore. Such waves also occasionally do great damage upon low lying coasts. (3) The rise in sea level due to the piling up of the water in the center of the storm by the inblowing winds often is very destructive. Indeed the sea level itself is sometimes raised more than 10 feet by this means, and the great waves sometimes reach heights of 30 feet above normal sea level. (4) The torrential rains commonly associated with typhoons frequently cause disastrous floods. Rainfall in excess of 30 inches in three days is not rare in connection with typhoons and occasionally that much falls in 24 hours."[1]

"There are six regions of occurrence in the tropical parts of the great oceans, and it is a significant fact that the South Atlantic is the

[1] Stephen S. Visher, "Notes on Typhoons, with Charts of Normal and Aberrant Tracks," *Monthly Weather Review*, L (1922), p. 588. Washington: U.S. Weather Bureau, 1923.

only ocean in which these storms never occur. The regions are as follows:—

(1) North Atlantic Ocean. The West Indies, the Gulf of Mexico, the Caribbean Sea and the Florida Coast.
(2) North Indian Ocean. Each side of India, in the Bay of Bengal and in the Arabian Sea.
(3) South Indian Ocean. To the east of Madagascar, near the islands of Mauritius and Réunion.
(4) [Coastal seas of Australia, between 110° and 160° E. Longitude.]
(5) North Pacific Ocean. Over the China Sea, the Philippine Archipelago and Japan.
(6) South Pacific Ocean. From the east coast of Australia to Tahiti.

At least 90% of the hurricanes recorded in the last 40 years have originated in these areas."[1]

"The terms 'hurricane,' 'typhoon,' and '[tropical] cyclone' are applied to the same type of storm. . . . . In all storms of this class the surface winds blow more or less spirally inward toward an area of minimum atmospheric pressure, then upward and outward at elevations varying with the extent and intensity of the storm. The term 'hurricane' is restricted to . . . . the West Indies and neighboring waters of the North Atlantic [and to the Western South Pacific and Australia]. The storms occurring in tropical regions of the North Pacific are called 'typhoons.' In the Indian Ocean they retain the name originally given them by the early English mariners, namely cyclones. . . . . Tropical storms are accompanied by a great fall in the barometer, resulting in [destructive winds and heavy rainfall]. In the tropical storm there is a moderate decrease in pressure to within 40 or 50 miles of the center, and then a rapid fall. . . . . This steep pressure-gradient marks the area of the destructive winds and the excessively heavy rainfall which are characteristics of the tropical storm. . . . .

"Conditions favorable for the formation of hurricanes in the West Indies begin in the month of June, but do not become well developed until the month of August. From August to the close of October is the real period for these storms, as is shown by the following figures of frequency during a period of 35 years:

[1] E. V. Newnham, "Hurricanes and Tropical Revolving Storms," *Geophysical Memoirs*, No. 19, pp. 229–230. London: Meteorological Office, 1922.

	May	June	July	August	September	October	November	Season
Frequency	1	8	5	33	43	42	2	134
Per cent	1	6	4	25	32	31	1	.....

"The essential similarity in the structure and intensity of these tropical storms [in all the regions in which they occur] has already been referred to. They are formed under similar conditions and move in similar paths although in widely separated areas."[1]

AVERAGE ANNUAL FREQUENCY OF RECORDED TROPICAL CYCLONES[2]

Region of Occurrence	Number of Severe Cyclones	Number of Lesser Cyclones	Percentage of the Total Occurring in the Autumnal Half of the Year
Western North Pacific (110°–140° E. Long.)	10	20	77
Central North Pacific (140° W.–140° E. Long.)	2	6	75
Eastern North Pacific (140°–80° W. Long.)	2	3	85
West Indian Seas	3	2	76
Arabian Sea	2	2	50
Bay of Bengal	2	6	80
South Indian Ocean	8	5	83
Australia and Coastal Seas (110°–160° E. Long.)	5	8	80
Western South Pacific (130° W.–160° E. Long.)	5	10	82

THE HURRICANE OF AUGUST 7–20, 1899, IN PORTO RICO[3]

"On the 8th of August, 1899, one of the most destructive storms in the history of Porto Rico passed directly across the entire length of the island. More than 3,000 lives were lost, mostly from drowning; the high winds and heavy rains completely destroyed a maturing coffee crop valued at over $7,000,000; the plants of the banana and plantain, which furnish the principal food supply of the mountain people, were mostly uprooted, while the frail houses of the natives were with few exceptions wrecked by the winds or swept away by the floods. . . . .

[1] Oliver L. Fassig, "Hurricanes of the West Indies," *U.S. Weather Bureau Bulletin X*, pp. 7–8, 11. Washington: U.S. Weather Bureau, 1913.

[2] Adapted from S. S. Visher, *Tropical Cyclones of the Pacific and Their Effects*. Honolulu: Bishop Museum. (In press.)

[3] Oliver L. Fassig, *op. cit.*, pp. 19–22.

"The center passed northward of Ponce and Juana Diaz, and very near to the latter town. Reports from Ponce showed a loss of over 500 lives, mostly by drowning. The smaller fruits and vegetables were reported as utterly destroyed, and as these, with bananas, are the principal food of the inhabitants a famine was inevitable. The observer at Juana Diaz reported a rainfall of 11.20 inches from 6 A.M. of the 8th to 6 A.M. of the 9th. Along the military road from Coamo desolation reigned on every side; but two houses were left standing at Aibonito, in the mountain pass, and the road between these towns was blocked in many places by huge bowlders which were blown and washed down from the cliffs which border the road.

"[At Arecibo] the flood of the rivers which, by a common mouth, empty into the sea near this town, was such an enormous one that old people here have no recollection of anything to equal it. The loss of life by drowning is estimated between 500 and 1,000. Almost all the houses or the peasants living in the plains and higher up along the river sides have been carried to the sea or destroyed, while the lower part of the town was several meters under water. . . . .

"In the city [of Mayaguez] the damage to property was large, and from the country the news is appalling. One-fourth of the coffee crop only will be saved; the loss of cane was considerable, and crops of minor fruits, which are the sustenance of the poor, have disappeared. The loss of life is greater than ever before, houses with all inmates being washed away by the floods."

DESCRIPTION OF A TYPHOON AT SEA[1]

"At daylight I crawled out. . . . . The storm was at its height. The wind was coming in gusts that reached 120 miles an hour. The air was simply filled with the white spume of the sea, just as the air is filled with snow in a great storm at home. To windward it was impossible to see more than 100 feet and to leeward not much farther. Yet through this white welter we could see something of the heights and depths that hemmed us in more than masthead high, with writhing slopes like the sides of mountains.

"The wind pitched itself at us with a force that made the gale of the night before seem puny and ineffective. Altogether it was an exhibition of violence unsurpassed. The nearest approach to it is afforded by Niagara Falls, as you ride up to the foot of the tumbling

[1] Paul R. Wright, quoted in *Monthly Weather Review*, XLVII (1919), p. 660. Washington: U.S. Weather Bureau, 1920.

waters in the Maid of the Mist, or walk under them to the Cave of the Winds. But here both air and water were like a Niagara let loose and driving themselves down upon our little steel ship. Against the unprotected face the hard-driven spume stung like the flying particles of a sandstorm."

Tropical cyclones spend their force soon after striking continental land masses, and therefore generally affect interior points only in the shape of heavy downpours and high winds.

HIGH ALTITUDE CLIMATES IN THE LOW LATITUDES

In both low and middle latitudes the climate of highlands differs significantly from that of lowlands. But whereas in middle latitudes living conditions become harder with increasing elevation, in low latitudes many highlands support a larger population than do adjacent lowlands. It is difficult to generalize on low latitude highland climate because slight differences in altitude or land forms create sharply contrasted climatic types. Since no two highland regions are identical in these conditioning factors, no two have exactly the same climate.

Four types of highland areas within the low latitudes may be recognized: (1) mountain slopes and shoulders of medium elevation; (2) plateaus of intermediate elevation; (3) lofty plateaus, and (4) high mountain tops.

One of the most important climatic boundaries within the tropics is that between lowland and highland. In nearly every low latitude region there are local names for the different levels. The distinction is fitly expressed in the Spanish of Middle America by the terms *tierra caliente* (hot land) and *tierra fria* (cold land). The *tierra caliente* embraces the several lowland climates, which reach up the slopes of the mountains to varying elevations, depending upon the latitude. Where deep valleys are carved into the highlands ribbons of *tierra caliente* may run into the general area of *tierra fria.* Certain valleys which dissect the Abyssinian Plateau are filled with jungle green, inhabited by hippopotami and smaller denizens of the rainy low latitude climate, and infested with malarial mosquitoes.

The *tierra fria* is the land of hot sun and cool shadow. Blazing heat radiates from open field and pavement, but within buildings, or even in the black shadows cast by trees, it is cool. The evenings de-

mand light wraps, and the early mornings are likely to be uncomfortably chilly. Inhabitants of highlands recognize a number of subdivisions of the *tierra fria*. The long slopes of high mountains run the whole scale of climates, capable of producing, at one level or another, almost every plant known, from equatorial rain forest to high latitude tundra, temperature on the average decreasing 3° F. for each 1,000 feet of rise. Natural vegetation varies with exposure to sun and wind, with steepness of slope, and with orientation of the slope to moisture-laden winds.

Just above the *tierra caliente*, on mountain slopes and shoulders, lies a zone known in Middle America as the *tierra templada*, or temperate land. It is the most truly "temperate" climate in the world, varying only 4° or 5° F. from season to season, even 20° of latitude from the Equator. The slopes are bathed much of the time in cloud, which helps to keep the temperature equable and rather lower than it otherwise would be (between 65° and 75° F.). This cloud, which the diurnal drop in temperature converts into mist, reduces evaporation from the surface to a minimum and, with the rains, produces a lush, natural vegetation of the most varied sort—broad-leaved trees, tree ferns, lianas, mosses—so dense that paths through them are like tunnels in some places, e.g., the eastern Andes. This zone is capable of growing the most diverse crops. In Southern Mexico sugar cane, maize, and wheat may be seen side by side on the same farm. The *tierra templada* is the coffee belt of Middle America and the East Indies, and most of the highlands of these two regions, as well as those of Indo-China and Kenya, Africa, lie within this zone. Coffee is a notable example of a plant which thrives best in the shade of larger trees. Hence, suitable trees are left when the forest is cleared, or planted if the native forest is inadequate. Other plants, such as tea and tobacco, which likewise require shade, are covered by slats, muslin, or mosquito-bar. In places where winds occur, windbreaks are arranged to protect plantation trees likely to be injured. Windbreaks also are used to fend off sudden changes of temperature, because most low latitude plants are susceptible to exceedingly slight variations. As a rule they do not germinate unless the temperature is at least 75° F. but excessively high temperature is as damaging as low temperature.[1] In some parts of the low latitudes, Europeans, settled on the

[1] The need for shade and for protection against wind and temperature change is not confined to crops of the *tierra templada*, but applies as well to all low latitude climates, and even to the subtropical types. Cacao requires both shade and windbreak, citrus fruits have to be protected against temperature change, and most nursery stock is started under slat frames.

plains, have established resorts within the *tierra templada* where they go to escape the hottest season of the lowland. "Hill stations" of this type have grown up in the East Indies, Ceylon, the Philippines, Brazil, and some of the West Indies.

Above the *tierra templada* lies the true *tierra fria*, the lower limit varying with latitude and with land form from approximately 9,000 feet at the Equator to about 6,000 feet near the tropics. The temperature is lower, the rainfall less heavy, and the vegetation consequently less luxuriant than in the *tierra templada*. Most of the hill stations of India are situated on mountain shoulders in the lower *tierra fria* (Dalhousie, 5,500 feet; Naini Tal, 6,400 feet; Mussoorie, 6,500 feet; Simla, 7,000 feet; Darjeeling, 7,000 feet; Murree, 7,500 feet). The major development of true *tierra fria*, however, is found on plateaus and in intermontane valleys. The principal highlands of Abyssinia, Kashmir, Peru, Ecuador, Colombia, and Mexico lie within this zone. The Central Plateau of Mexico may be singled out as illustrative of them all.

Lying between 18° and 22° N. Lat., with a maximum altitude of 7,500 feet, the Mexican Plateau receives about one-fifth as much rain as does the *tierra templada* in the same latitude. Nearly all this rain falls during the warmer months (June-October) in the form of afternoon or night-time convectional showers, frequently accompanied by thunder and lightning. Snow occasionally falls in the colder months, but soon melts under the intense sun. The average precipitation is light. Low relative humidity results in a high rate of evaporation. This, coupled with light and concentrated rainfall, inclines the climate toward aridity. Irrigation is practiced wherever water can be obtained, and alone makes possible the truck farms which are a conspicuous feature of the landscape about the City of Mexico. Wheat and maize may be grown without irrigation; maguey, a variety of cactus and a principal crop, is planted even upon hillsides where rapid drainage reduces the soil moisture to a minimum.

The natural vegetation on the plateau is grass and scrub—mesquite, yucca, and agave—except where alkaline or porous, sandy soil is barren. Even the foothills and lower slopes of the mountains are devoid of timber trees, although whether this is a result of climate or deforestation is undetermined. On the upper slopes, extending to timber line (11,000–13,000 feet), are spruces and firs. The grazing of cattle is a business of some importance, less predominant, however, than on other highlands of the same climatic type, as for example that about Bogotá (Colombia).

The seasonal range of temperature on the Central Mexican

Plateau is small, averaging 4° F. (59° F. in the coolest month and 63°F. in the warmest). The maximum range scarcely exceeds 10° F. These figures, however, conceal the most noticeable fact about the temperature, viz., the diurnal range of some ten degrees, which is intensified by the blazing sunshine. Despite cold nights, the hot days throughout the year mature not only barley, wheat, vegetables, and apples, but also maize, which in fact is a staple crop. The nights, chilly even in the warmest month, and often touched with light frost during the opposite season, enforce the custom of wearing shawls, overcoats, and the native *serapes* in the evenings and early mornings. Houses are not equipped with heating devices, but are built to gain as much sunshine as possible. Nevertheless, pedestrians at midday seek the shady side of the street in order to avoid the burning rays of the sun, intensified by reflection from pavement and walls.

This plateau was the center of the advanced Aztec civilization which the first European explorers found, and is today the seat of government and the most populous section of Mexico, its climate being entirely suited to people of European extraction. The rural population averages eight per square mile on the highland, but only two per square mile in the adjacent *tierra caliente*.

On very high table-lands the climatic extremes due to altitude are exaggerated to an unpleasant degree. The Bolivian Plateau, between 15° and 21° S. Lat., and some 12,000 feet above sea-level, is illustrative of this phase of the *tierra fria*, called locally the *puna* (bleak region). This climate has made a tremendous impression upon visitors.

"Early in the morning and late in the evening, when the sun is below the horizon, the cold is liable to be intense even in September and one suffers from almost frozen feet. In the winter, when the winds blow and the frosts are yet more severe, the dry cold is so trying that even the natives cover up their faces in thick woollen masks, and wrap shawls about their heads and ponchos over their bodies. But as soon as the sun is a little way above the horizon, its direct rays scorch the traveller with their great heat, so that he soon begins to pray for the night, as the lesser evil of the two. . . . . By day the burning sunshine so envelops all the brown, dry, dusty ground that everything in view seems to vanish in brightness; and the eye, unprotected by dark glass, cannot gaze steadily in any direction. . . . . When the sun is hottest little cyclones raise dust whirlwinds which dance along, often by scores at a time."[1]

[1] Sir Martin Conway, quoted in W. G. Kendrew, *The Climates of the Continents*, pp. 321–322. Oxford: The Clarendon Press, 1922.

Newcomers to the region are liable to "mountain sickness" because of the rare atmosphere, and lowlanders rarely, if ever, become sufficiently acclimated to perform manual labor. The natives, on the other hand, can work in the mines or jog briskly up and down the hills which ridge the plateau without apparent discomfort, yet if taken to the lowlands they become ill. They are noted for abnormally large chest development.

The average seasonal variation of temperature amounts to only some 10° F., but the daily range is much wider. At La Paz, for instance, the thermometer is likely to register between 60° and 70° F. in the early afternoon during the warmer season, but it falls to 45°F. during the night; in the colder months it ranges from 50° or 60° F. to something below freezing. But these figures record shade temperature, and so do not bring out the full force of the diurnal variation, which lies in the great contrast between the cold of night and the heat of midday sunshine. The mere passage of a cloud over the face of the sun causes a sharp drop in temperature. The natives seek the sunshine, and even do their cooking out of doors, in order to escape the chill which pervades interiors of buildings.

The abrupt changes in temperature result in violent winds, which vary in character and direction from place to place and from season to season. From July to September, chill winds which often mount to gales sweep the plateau, carrying clouds of dust. At Oruro these winds are called "The Harvest of Death" because of the bronchial troubles which follow in their wake. Over much of the region the wind picks up after midday and decreases in violence with nightfall. At Cochabamba it begins to blow regularly at 3:00 P.M. Although the data are not decisive, there appears to be an indraft of air from all sides of the plateau, centering over the large salt pan at about 20° S. Lat.

In spite of inblowing air, the precipitation which it brings is so light that the plateau is semi-arid. Nearly all the rainfall is concentrated into the three warmer months, December to February. Most of it falls in convectional thunder showers during the afternoon or night, and may take the form of snow, rain, or hail at all seasons. Lightning and thunder are especially intense. Fluctuations in distribution of precipitation from year to year are marked. During the rainy season the stream beds fill and the salt pans turn into shallow lakes which gradually evaporate in the ensuing dry weather. The air is extraordinarily clear, particularly during the dry season.

The short, cool growing period and the light rainfall severely restrict natural vegetation. At the higher levels are bunch grasses

and bushes. Many of the plants resemble cushions of closely packed leaves; buds and flowers are protected from hail by the leafy armor in which they lie imbedded, and flowers open only when the sun is shining. After a rain these plants are spongy with water, which they retain for a long time despite intense insolation. Most of vegetation on both higher and lower levels has small leaves, leathery above and downy below, sure indication of high resistance to evaporation. On the lower parts of the plateau, plant life is slightly more varied than at the high levels. There is even a scrubby tree which furnishes sticks for timber. Nevertheless, wood is so scarce that buildings, and even telegraph posts, are made of adobe or stone.

The natural vegetation varies little from season to season, but the few cultivated crops are produced in the warmer months. Potatoes, a native grain called *quinoa*, haba beans, alfalfa, and barley make up the list. The barley does not mature, and can be grown for fodder only in the lower and sheltered districts. Where water can be had, irrigation is practiced, but most of the irrigated valleys lie so high that they can be used only for meadows. The few irrigable valleys at lower elevations contain the densest population in the region, e.g., Cochabamba. Most of the area is devoted to the pasturing of sheep. The scanty herbage compels the herders to adopt a semi-nomadic existence. They supplement grazing with tillage on patches of ground which are selected for deep soil or nearness to water holes, and which produce crops without irrigation.

Animal life on the Bolivian Plateau reflects the dominating climate. The chinchilla and the vicuña, both indigenous to this highland, are famous for their heavy fur, and the llama and alpaca, believed to be domesticated forms of the vicuña and the huanaco (another native), provide wool. To these local species have been added the sheep, now the mainstay of the farmers and the producers of most of the wool used in the native clothing. Features of this clothing are the heavy felt hats and the thick woolen ponchos.

Tibet is the only other extensive plateau of the *puna* type. Although outside the tropics, it is much like the Plateau of Bolivia.

Above habitable plateaus and the timber line of mountains in the low latitudes lie the chilly and misty *páramos* (bleak moors), where tongues of glaciers intrude into a mat of mosses and stunted bushes similar to the tundra of the subpolar climate in high latitudes. This zone is narrow; its upper limit is the permanent snow line, which lies at about 15,000 feet near the Equator, and progressively lower toward

the tropics. Scanty precipitation in certain intermontane valleys results in an exceptionally high snow line: on inner slopes of the Central Mexican Plateau 15,000 feet; on the eastern and western rims of the Bolivian Plateau 18,000 and 20,000 feet respectively.

Above the snow line rise peaks shunned even by the hardy native animals, and devoid of vegetation. Mountain climbers occasionally venture into these fastnesses for the sake of adventure or science, but the difficulty of breathing at such heights, the likelihood of fatal missteps, and the danger from snowslides and storms restrict the number of these adventurers. During the past few years two expeditions sent out under the auspices of the Royal Geographical Society of London, amply financed, manned by the pick of British mountaineers, and preceded by a careful reconnaissance survey, have failed to reach the top of Mount Everest owing to the brevity of the season when storms are at their minimum intensity. Moreover, both attempts were marked by loss of life.

TEMPERATURE CONTRASTS BETWEEN CALCUTTA AND DARJEELING, INDIA

Average Monthly Temperatures in Degrees Fahrenheit

Month	Maximum		Minimum	
	Calcutta	Darjeeling	Calcutta	Darjeeling
January	77	47	56	35
February	82	48	60	36
March	91	56	69	42
April	96	63	76	49
May	95	64	78	52
June	92	66	79	56
July	88	66	79	58
August	88	66	78	57
September	88	65	78	56
October	87	61	74	50
November	82	55	64	43
December	77	49	56	37

CLIMATE AND CIVILIZATION IN THE LOW LATITUDES

For the most part the indigenous civilizations of regions having the low latitude types of climate are primitive. It seems probable that the climate is partly, perhaps primarily, to blame for this backwardness. The people of the rainy regions are enervated by the humid heat, discouraged by the transcendent vegetation, and tempted to sloth by nature's abundance. Those of the desert, on the other hand, after making swift progress for a time, find their activities circumscribed by a limited supply of water and by separation from the rest of the world. In the semi-arid regions society is perforce attuned to the tribal organization and unfixed habitation of the nomad. Only in India, in the wet-and-dry type of climate, has a first-rate civilization developed; even there it has been reinforced at intervals from the middle latitudes, and today a vast area with 320,000,000 people is governed by a handful of British, representing a nation of only 45,000,000 middle latitude folk.

In brief, the support furnished by the indigenous economic life in regions having the low latitude types of climate has sufficed for only a sparse population, except in India, Java, and the Guinea Coast, and has yielded little or no surplus upon which an advanced civilization could be based.

THE CLIMATE OF WEST MARGINS OF CONTINENTS IN LOWER MIDDLE LATITUDES, OR THE DRY SUBTROPICAL TYPE OF CLIMATE

This type of climate, which often is called "Mediterranean" because of its extensive development about the Mediterranean Sea,[1] is characterized by a moderate range of temperature from season to season. This seasonal range of temperature is greater than that of any low latitude type of climate, but it is considerably less than that of most other middle latitude types. No part of the year is cold, but the season during which the sun's rays are most oblique is cool.

[1] "Margin of the continent" describes correctly the portion of the Europe-Asia-Africa land mass having this climate only if the Mediterranean Sea be thought of as an extension of the ocean.

Light frost may occur almost any night in the cool season, but killing frosts are rare, and a few feet of elevation above a basin or valley floor insures frost-free winters in most years. The rest of the year is warm to hot. The growing season for hardy plants is almost or quite twelve months long; "subtropical" is a common characterization of this climate. The diurnal range of temperature is marked.

Precipitation is moderate to scanty, in most places less than 30 inches annually. All or nearly all the rain falls in the cool season, generally in the form of short, heavy showers, most of which occur at night. Nevertheless, there are periods when it rains for hours, or even for days. Lightning and thunder rarely accompany these downpours.[1] In some places and in some years the heaviest rains usher in the rainy season, but there is a great deal of variation in amount and distribution. Probably no other humid lowland climate shows such wide divergence in precipitation from place to place. Save on the northern Mediterranean borders, snow is almost unknown, and remains on the ground only a few hours on the rare occasions when it does fall. Two or three days of snow a year are expected in the Northern Mediterranean region.

Owing to the sharp rise of temperature during the day and reciprocal fall during the night, relative humidity varies widely in each twenty-four-hour period. In winter the days march in bright, cloudless succession, broken only occasionally by rains. In some regions an early morning fog rises over low spots, only to be dissipated by the ascending sun. The nights are likely to be damp and chilly, even when no rain falls. The summer days feel dry, but a thin haze veils distant objects. As the sun descends through the dusty strata of air near the earth, the deep-blue sky is transformed to gold or red for a few moments, after which night closes in almost without twilight. Within an hour or two fog drifts in from the sea, and in some places as much as .01 inch of moisture may gather on exposed surfaces before morning. The summer fog is dissipated by 10:00 A.M. at the latest. There is a sharp decrease in relative humidity from the coast inland, and some regions, particularly those cut off from the ocean by hills or mountains, do not experience the night fogs. Cloudiness is not typical of the summer climate.

In summer the wind rarely exceeds a light breeze, but variable

[1] In Chile thunder is said to cause as much terror as an earthquake; in South Africa it is almost unknown; in California it is rare; but in some parts of the Mediterranean world it seems to occur not infrequently.

winds, common to all middle latitude climates, blow in winter. In addition, some regions are more or less frequently visited by strong winds which bring unpleasant weather.

Natural tree and bush growth in the dry subtropical type of climate is rather sparse and scrubby, owing to the long dry season. The cork oak and the live oak are among the largest native trees; they are spaced far apart, and generally occupy valley floors. Perhaps the most widely known tree characteristic of this climate is the olive. Grown mostly without irrigation in a climate with a long, hot, dry summer, the olive tree nevertheless thrives, for it possesses certain characteristics that fit it well to its environment. It has an extensive root system, widespread rather than deep, and thus draws moisture from a wide radius. Its bark is thick and corky and its leaves are small and leathery, so that it transpires relatively little moisture into the air. On the other hand, since there is no season of leaf fall, the plant is ready in the autumn and the early spring, as well as in the mild winter, to carry on its growth. The olive tree grows satisfactorily on otherwise uncultivable hillsides. Therefore, in the hilly country which makes up a large percentage of the total area in most of the regions having the dry subtropical climate, it provides a valuable addition to the rather restricted agricultural output. Olive oil, which is pressed from the ripe fruit, is a staple in the diet of the people about the Mediterranean Sea, furnishing the needed fat element in food which butter supplies in many parts of the world. Grass and many other herbaceous plants make the ground green during the rains, but in the dry season the landscape becomes a parched brown or yellow, except in the irrigated patches.

Agriculture in regions with this climate has such clearly recognizable characteristics that it has come to be called "Mediterranean agriculture." Typical perennial crops are olives, oranges, lemons, deciduous orchard fruits, and grapes. The fruits must be irrigated during the annual summer drouth, but olives may be grown without irrigation. The cereals, chiefly wheat and barley, commonly are grown as "winter" crops planted at the beginning of the rains and harvested in the dry season following them. Annual crops grown during the summer must be irrigated. The production of dried fruits, such as raisins, prunes, and currants, is a notable feature of this dry and sunny climate.

The dry subtropical climate is one of the pleasantest in the world. In summer, in spite of the high daytime temperature, sensible temper-

ature is low; the nights are cool and foggy except where mountains shut out air currents from the sea. In winter the temperature never falls much below freezing, so that elaborate heating systems and heavy clothing are unnecessary. Nevertheless, the weather often is chilly at this season. Throughout the year there is a great deal of sunshine, and life out of doors is attractive at all seasons. Many people find the wide daily range of temperature bracing, although to some it is trying. The Riviera of France and Italy, the Crimea, and Southern California are world-famous winter resorts.

SAVING THE CROPS FROM INJURY BY FROST[1]

"'A penny saved is twice earned,' said Franklin, and one can not help wondering what that wise old gentleman would say today about . . . . the problem of saving crops from injury by frost. . . . . Is it not wise . . . . to study natural wastage in all its forms? For Nature herself is the master spendthrift; and the yearly losses through natural conditions, such as droughts, pests, and frosts, easily exceed the savings of the community for a long period. . . . .

"Frost is largely a matter of *local air drainage*. Frost can be mastered and, indeed, has been mastered in some localities. The word "frost" has been used in three different senses: first, a freezing temperature; second, the spicular ice crystals; and third, the damage resulting from defrosting or frosting. The first is an erroneous usage and should be abandoned. . . . . When water vapor in the air near the ground changes its form directly into ice we get the familiar spicular or pointed crystal which most of us call frost. It does not go through the intermediate state of being water, else frost would be frozen dew, and all the flakes would be little globes. After a still, clear cold night, with neither too much nor yet too little moisture present, we find next morning crystals covering the grass and lower foliage, and most of us think, if the deposit is at all heavy, that much damage has been done. If later the plants shrivel and blacken we think that the crystals did the mischief. On the contrary, Nature, through the agency of these crystals, was trying to cause a delay or lag in the cooling. By this very same method, which we shall later explain, namely the utiliza-

[1] Alexander McAdie, *Geographical Review*, IV (1917), pp. 351–358.

tion of the fact that ice has a high specific heat compared with that of air, delicate flowers may be saved in freezing weather. It may run counter to our established notion to say that frost crystals protect vegetation from injury, but they do. The destructive factor is the fall in temperature and the consequent expansion and contraction of the plant tissue and juices in opposite directions. More frequently still the damage is due to a sudden rise in temperature after refrigeration. Probably it is the strain to which cells are subjected by rapid warming after chilling which does most of the damage known as frosting. It is not the freezing but the thawing which works the mischief. The writer found in the orange groves of California that in two hours the rise in temperature might amount to ten or fifteen degrees, i.e., at a rate far exceeding that at which the temperature fell, and, what was still worse, the upper side of an orange would be warm and the under side still frozen. The damage was nearly always greatest where the fruit was freely exposed to the rays of the rising sun, and, other things being equal, a southeastern exposure was the worst. The remedy is cold water or a light smoke cloud, for we must check the sudden rise in temperature.

"How shall we prevent or minimize the damage? We can do this, but not without some effort and at some expense. The fight, however, is worth while, as has been proved by the campaigns in the great fruit belts on the Pacific Slope. A brief review of what has been done in California will encourage the doubters.

"One day in December, 1895, the general forecaster at San Francisco issued warnings of frost. The press of the orange belt made merry over the warning, but, to their surprise and discomfiture, the frosts came and the losses were heavy. A few horticulturists in Riverside met to talk over the situation and the forecaster was called in for consultation. Within a month one of the members had designed and tried out a wire basket, suspended about three feet above the ground and holding about ten pounds of coal with the necessary kindling. That was the first of modern frost protectors, the Copley coal basket. Other members tried movable smudgers and heated water suppliers, and on one ranch a covering of laths was tried, which, although expensive, proved its worth. A few years later came the first oil burner for use in the vineyards near Fresno, and from this all the present forms of orchard heaters have been developed. Eighteen years later, during the first week in January, 1913, the same forecaster had occasion to issue frost warnings, but with very different results,

for the press spread them far and wide, leaving no stone unturned in urging the growers to smudge and fire *early*. It was necessary, for there followed the severest weather ever known in that section; and the battle was fairly joined between Nature and Man. Man won. There were plenty of thrilling experiences in this fight, and much could be told if time and space permitted. Moreover, in this war between man and nature there can be no end, for the fighting must be renewed as long as the seasons come and go.

"How does the forecaster know that frost is coming? Chiefly by anticipating for the given localities a certain type of air flow or circulation near the ground, which is largely determined by the lay of the land. To the general movement of storm areas and the accompanying winds he must add the cumulative effect of much gentler currents, so slow indeed that they might be called "creeping" currents. When a barometric depression, or "low," as it it is called, moves briskly eastward and is followed by an anti-cyclonic circulation, or "high," as shown by the surface isobars, the latter will at certain times seem to settle down and stay quiescent for sixty or more hours. A stagnant "high" gives results quite different from the ordinary interchange of air. There is an absence of convectional currents; there is no mixing of the different layers of air; and, to use the term of a foreign meteorologist, there is no *churning*. This lasts for two, three, and sometimes four days and nights. It is easy to see now why frosty nights follow one another, why we seldom have more than three frosts in succession and why the last night may have the lowest temperature. It is also plain why still nights are frost nights and why there are no clouds, because whatever currents there are, are from above downward rather than upward. And finally the air, since it comes from above, is dry and pure, that is, free from dust and haze; and, while perhaps slowly heated by compression in falling, still it is not heated enough to overcome the chilling which follows from contact with the cold ground. And the ground goes on cooling all the more rapidly because the air is very pure and dry. Marked inversions of temperature take place, the cold air is down and can not get up and the warm air is up and can not get down. As a result of the slow side-drainage, shallow ponds of stagnant air are formed. The forecaster who has, besides his air maps, topographic maps, can follow the cold air down into the lowlands, for it is heavier, bulk for bulk, than warm air and unless prevented will roll itself to the bottom. The inclination of the valleys to the prevailing winds makes a difference. If the valleys are walled

in so much the worse. The nature of the soil counts, as well as the cover crop. Dark soils radiate more rapidly than light soils, while plowed and wet lands differ from unbroken and dry soils. Frost streaks are probably due to stagnant layers of cold air *resting* on chilled soils, for even a slow flow of the air will suffice to prevent frost. Crops on the hillsides escape for the double reason that the air is in motion and because the slopes front the level of warm air and, whatever flow there is, is from this warm level laterally to the slope.

"We have said that the streams of cold air are very shallow—often only a few meters in depth. If we can divert or disturb these we can prevent the rapid cooling of the ground by radiation. How, then, shall we protect? A hint has been given above, namely to follow Nature. If we can not control the circulation, then spread a cover to conserve the earth heat. The cloud is the cover which Nature spreads, and even a light fleece will do the work, for there is no frost on cloudy nights, even when the clouds are high. Assuming that the agriculturist has been warned by the forecaster, what shall he do? Forewarned is forearmed, it is said; but not in this case unless the grower has prepared a supply of fuel, covering material, water, sand or fine ash, and has available labor. The easiest way is to cover the plants with paper, cloth, straw, or mulch or make a cover of dense smoke by sprinkling water on small fires of brushwood soaked with oil. Or heat can be applied more directly by lighting many small fires or by using orchard heaters, which are metal containers holding about a gallon of crude oil. Large open fires are not effective because most of the heat goes into the higher levels, where it is not needed. The problem is to heat or displace a comparatively shallow stratum of air close to the ground. There is therefore no gain in having bonfires unless in some way a circulation can be established and warm air from above brought down. Unfortunately in most fields this is not the result, and the cold air is simply replaced by other cold air. The slight gain due to mixing and motion is not commensurate with the fuel used.

"Another method is to mix the air or ventilate by blowers or windmills; but if there is much of a draft and the air is dry, some provision must be made for moistening. Other and more available methods involve the use of substances having a high specific heat, such as water, sand, or wood ashes. Of course, flooding as practiced in the cranberry bogs is an old and effective preventive. On a smaller scale spraying with water that is moderately warm is good. A coating

of ice does not necessarily result in injury, provided that both freezing and thawing are gradual.

"For the average gardener or small fruit grower, however, the best method is that of covering. It is not exactly new, for our grandmothers knew enough to cover their favorite rose bushes, pinning paper over them and generally saving them. The one criticism is that the covering was easily displaced. The theory is simply that the heat waves re-emitted from the ground are intercepted by the cover, and the cooling of both ground and plant due to intensive radiation is stopped. It is wiser to use a more durable cover, preferably light waterproof material with proper fasteners. If soil and plant are well watered before the cover is spread, so much the better. And finally it is an advantage to cover *early*, that is, an hour or two before sunset rather than after. The method of direct heating has been used successfully in the fruit ranches of the West and Middle West; and about thirty oil pots to the acre will keep the temperature above freezing under average conditions."

WEATHER BUREAU FRUIT-FROST SERVICE IN SOUTHERN CALIFORNIA[1]

"The delivery value of the citrus crop of California during 1921 was fully $100,000,000. A larger crop than this, and of better quality, was on the trees on January 19, 1922, the date when the 'freeze' began. Three days later, fully fifty per cent of the crop had been damaged so severely by low temperature that it was a total loss, and a considerable portion of the remainder had been frozen to a degree that prevented its being included in the fancy grades.

"The law of supply and demand, through increased prices obtained for the fruit saved, operated to decrease the amount of the monetary loss to the industry as a whole; the delivered value of the 1922 crop was $95,993,485.58. However, the returns for the crop were so unevenly distributed among the growers, that the results were serious. Literally hundreds of orchardists received not one cent in returns, while others, who were located in districts where the damage was not so severe, or who saved their fruit through the use of orchard heaters, profited enormously.

[1] Quoted in *Bulletin of the American Meteorological Society*, IV (1923), pp. 17–18.

"But the frozen fruit was paid for by the consumer in higher prices, by the railroads in reduced freight receipts, and by the people who make their living in the harvesting and packing of the crop. Some packing houses did not open their doors during the season.

"Think of it, a loss to the country at large of more than fifty million dollars! Small wonder that the fruit growers are giving more serious consideration to the frost menace than ever before. Hundreds of thousands of new orchard heaters have been installed in the orange and lemon groves, and even now, near the close of a practically frostless season, heaters are still being purchased and made ready for service.

"Where residents of thriving tourist cities in the citrus belt were complaining bitterly about the smoke and soot connected with the protective operations a year ago, the business men are now organizing flying squadrons to aid the orchardists to fire the heaters.

"The Weather Bureau's minimum temperature forecasts and advices were so accurate, and the temperature records obtained in the three special fruit-frost districts were so valuable, that the service was extended at the beginning of the present frost season, through the assistance of the California Fruit Growers' Exchange, which appropriated $8,235 for co-operation. At the present time there are eight Weather Bureau employees engaged in this special work in southern California, in as many different fruit-frost districts. A total of 204 special temperature stations are in operation, all equipped with standard fruit-region instrument shelters and Weather Bureau minimum thermometers. Thermographs are located at 137 of these stations.

"It is the intention to continue the temperature survey work on this scale if possible, for five years, at the end of which time an accurate picture of temperature differences on cold nights will be available for use in making local application of minimum temperature forecasts, establishing a basis for an equitable system of frost insurance, and for making accurate estimates of the amount of damage following a killing frost.

"It has been stated that orchard heating increases the cost of production, and that this increased cost must be paid by the consumer. On the contrary, orchard heating increases the supply of marketable fruit, and through the operation of the law of supply and demand, the cost of the fruit to the consumer is lowered. Experience indicates that through expert advice and assistance to the fruit grower who wishes to protect his fruit, and by the issue of timely and accurate warnings of impending low temperatures, the Weather Bureau is directly respon-

sible for decreasing the loss of fruit by several per cent in a season like that of 1921–22. The economic savings thus realized amply justify the expense of maintaining the fruit-frost service for many years.—Floyd D. Young, Pomona, California, January 20, 1923."

ANNOYING WINDS OF THE DRY SUBTROPICAL CLIMATE

Hot winds originate in the deserts which adjoin several of the regions of dry subtropical climate. When these winds blow the temperature rises well above the normal; the nights, as well as the days, are hot (often 85° F. at midnight); relative humidity falls sharply (as low as 9% has been recorded at Los Angeles); and choking dust may obscure the sun. The spell of weather during which these conditions prevail may last three or more days, although the dust storms rarely persist more than eight or ten hours. The effects of these desert winds always are trying—lassitude prostrates the energies, the skin cracks, dust coats everything, indoors and out. Sometimes destruction follows in their wake—plants are wilted beyond recovery, or crops are cut to pieces by the sand blast. Although these storms may occur at any time of year, spring and early summer is the season of greatest frequency. Nearly every locality where such winds blow gives them a different name; but they are best known under the appellations "Sirocco" and "Santa Ana."[1]

When the Sirocco blows over North Sicily "the sky is yellowish to leaden, the air is filled with a dense haze, which blots out the sun or shows it only as a pale disc. People feel exhausted and oppressed, and disinclined for mental activity; animals also suffer from these hot, dry winds. Everybody stays at home as much as possible and does nothing. When the Sirocco is particularly violent, its scorching breath injures the vegetation; the leaves of the trees shrivel and, in a few days, fall. If the storm sets in when the olive trees and the vines are in blossom, a whole year's harvest may be lost. Usually it is heralded by a haze which rises over the southern horizon and overspreads the sky; a dead calm falls, under which the sea lies as smooth

[1] "Sirocco" in Sicily and Southern Italy; "Santa Ana" in Southern California; "Leveche" in Spain; "Samoon" in North Africa and Syria; "Norther" in the Great Valley of California (not to be confused with the cold "northers" of the humid subtropical climate).

as a mirror; suddenly the storm breaks with raging force, lashing the sea to fury. For a time it increases in intensity, then slowly subsides or stops abruptly."[1]

Considerable areas of the northern half of the Mediterranean Basin have at times dry, cold winds which stir up dust and chill the marrow. In the western Mediterranean such a wind is called "Mistral." The Mistral influence centers in the lower valley of the Rhône, where it prevails 175 days a year. From this center the Mistral is felt as far west as the Ebro Valley, and as far east as Genoa. It is a northerly wind, hence its low temperature, but since it is accompanied by few or no clouds, and since the sun may be high, the face may be grilled while the back is being chilled. A similar wind is the "Bora," common along the coast of northern Dalmatia. It blows in winter more often than in summer, and unlike the Mistral, nearly always is attended by clouds. Other places where the same type of wind occurs are the Cilician coast and the eastern end of the Black Sea.

THE CLIMATE OF EAST MARGINS OF CONTINENTS IN LOWER MIDDLE LATITUDES, OR THE HUMID SUBTROPICAL TYPE OF CLIMATE

This type of climate occurs in about the same latitudes as the Mediterranean type, with which it shares the appellation "subtropical." Summers are hot, and favored coastal localities occasionally experience a winter with temperature above 32° F. most of the time, and no damage from the occasional light frosts. Sudden and decided changes of temperature are notably more frequent than on west margins of the continents, however, and short periods of weather below freezing ordinarily occur several times each winter. Light frost must be expected during three or four winter months, so that the growing season is nowhere twelve months long. A few times in every decade hard freezes grip most regions having this climate, causing damage or destruction to sensitive perennial plants. Summer weather is sultry—the temperature ascends above 90° F. on fifty or more afternoons of every year, the relative humidity is high throughout the warm season,

[1] Th. Fischer, *Studien über das Klima der Mittelmeerländer*, p. 37; No. 58 of Petermann's *Mittheilungen*. Gotha: Perthes, 1879.

and the daytime breeze nearly always is light. The daily range of temperature is moderate.

As suggested by its name, the humid subtropical climate is characterized by abundant precipitation throughout the year. During the winter, periods of fair weather alternate with rainy spells, when drizzles may persist for twelve, twenty-four, or thirty-six hours. Snowfalls occur every winter; along coasts the snow generally turns to rain or melts as it reaches the ground, but inland, along the poleward margins of some regions, as much as twelve inches may accumulate. Most of the summer rain falls in torrential thunderstorms, which may occur in any month, but are most frequent in the two months following the summer solstice. In Southeastern Australia such storms average thirty-two a summer, and in Southeastern United States the average is fifty or more in most places. As much as 1 inch of rain frequently falls in an hour, and several stations hold records of more than 8 inches within a single twenty-four-hour period. The most prolonged winter drizzles rarely precipitate as much moisture as falls in an ordinary summer shower. Hail sometimes accompanies thunder-showers, with occasional damage to crops and buildings from hailstones. Such damage nearly always is confined to small districts, and inland areas are visited more frequently than coasts. It has been estimated that during an average year there is one rainy day to two-and-a-half fair days, but the distribution from month to month varies considerably in successive years. Autumn is the least rainy season, but in coastal areas rain commonly interferes with the harvest.

Throughout the year the winds are variable in direction and in velocity, although as a rule they are stronger in winter than in summer. In Central China the predominant variability is alloyed with a monsoon influence, which is not apparent in the other regions having this climate.

All regions in the humid subtropical climate are subject to occasional visitations by unpleasant or destructive storms. Both the West India hurricane and the typhoon occasionally reach extra-tropical coasts, where they are almost sure to work havoc because of the dense populations, the large cities, and the comprehensive harbor works characteristic of middle latitudes. In the Pampas of South America sultry northerly winds[1] are feared because of the lassitude and disease they occasion. They blow in summer. In Southern United States the "Norther," which comes in the winter, begins with a raw, violent,

[1] Called locally the "Zonda."

gusty wind. Presently the wind subsides and the thermometer drops sharply to below freezing. This cold snap may last a few hours or four or five days. Crops are injured, and people in their uncellared, thin-walled houses huddle about the cook stoves or open fireplaces in a vain effort to keep warm. On the coast of New South Wales a distinctive feature of spring and summer weather is the "Southerly Burster." It often causes a fall in temperature of 30–40° F. within twenty-four hours, and brings violent, squally winds, and very often thunderstorms. It increases the hazard of shipping off the Australian coast. A similar wind is characteristic of the Pampas except that it is dry.[1]

The natural vegetation in the humid subtropical climate is varied. Forests predominate, with three distinctly different types: evergreen broad-leaved, deciduous broad-leaved, and coniferous.

The agricultural possibilities of this climate are unexcelled. In the South of the United States and in Central China typical spring-sown crops that thrive in the long, hot summers of abundant rainfall are rice, corn, and cotton. In Central China and Japan fall-sown grains, such as wheat and barley, may be grown on the same fields that during the summer carry rice or corn, for the winters are mild and have a moderate rainfall. Nevertheless the early approach of the hot and humid summer makes the harvest season for these fall-sown cereals unpropitious. In Southern United States fall-sown cereals are cut green for forage. The practice of raising two crops a year on the same field is confined to densely populated regions, where the demand for foodstuffs is intense. Perennial crops, such as mulberry for the silkworms, and tea, are widely grown in the parts of Eastern Asia possessing this climate, the mild winters and the long, hot, humid summers being highly favorable to the growth of these plants. Citrus fruits are raised in the equatorward margins of humid subtropical regions, although not without considerable losses from the Northers. It is because many crops indigenous to the low latitudes can be grown in both the west and east margins of continents in the lower middle latitudes that these types of climate have come to be called "subtropical." Nevertheless, most cultivated plants are inactive when the temperature falls below 40° to 50° F., so that active growth ceases in the winter season in the subtropical climates.

Everywhere in this type of climate, population is relatively dense, as a result of agricultural productivity. The suitability of this

[1] Called by South Americans the "Pampero."

climate for Europeans is in dispute, however, as evidenced by the introduction of colored races into Southern United States and Natal.

AVERAGE TEMPERATURES IN DEGREES FAHRENHEIT FOR ATLANTA, GEORGIA; LOS ANGELES, CALIFORNIA; GENEVA, SWITZERLAND

	Atlanta	Los Angeles	Geneva
Annual	61	60	49
January	42	53	32
February	45	54	36
March	52	56	41
April	61	58	49
May	70	61	56
June	76	65	62
July	78	67	67
August	76	69	65
September	72	67	59
October	62	62	49
November	52	58	41
December	45	55	36

THE CLIMATE OF WEST MARGINS OF CONTINENTS IN HIGHER MIDDLE LATITUDES, OR THE MILD-WINTER-MILD-SUMMER TYPE OF CLIMATE

For the latitude this type of climate shows a strikingly small range of temperature. The summers are so cool that days of uncomfortable heat are uncommon, and stretches of sweltering weather occur only once in several years. On the other hand, freezing temperature, which appears several times a winter, rarely lasts long, and the winters should be thought of as mild or cool, rather than cold. Throughout Northwestern Europe people depend on open fires for heat. Snow falls occasionally during a month or two of winter, but seldom remains long on the ground. Because of the mild winters, spring opens about March (in the Northern Hemisphere), and advances apace during April; likewise autumn conditions hold over until a few weeks before

the winter solstice. In addition to the slight seasonal variation, the diurnal range of temperature is very small in winter, and only moderate in summer.

This is one of the rainier climates of the earth, despite the fact that the total annual fall averages less than that of the humid subtropical climate. Nearly all the precipitation comes in the form of gentle drizzles, predominantly at night, and some three-fourths of the year's total falls in the six cooler months. People think nothing of going about their ordinary affairs in the rain, because it is so frequent and because the raindrops are so fine they do not penetrate woolen clothing. Summer is the least rainy season, and in places lying in the lee of mountains, such as the Willamette Valley of Oregon, a month or two may be practically rainless. On the other hand, situation on the ocean side of the mountains means a great deal of rain in every month, as for example on the coasts of Washington and Southern Chile. During the wetter season, cloudiness is prevalent. In the less wet months, a light haze obscures distant objects, except at rare intervals, when it is replaced by bright sunshine. Relative humidity is high throughout the year. Sensible temperatures rarely cause discomfort in summer, but the winters are raw and damp. Fog is common along coasts.

One of the outstanding features of the mild-winter–mild-summer type of climate is the rarity of violent outbursts of weather. The wind is variable, but it seldom is strong. Thunder squalls are almost unknown, and torrential rains accompanied by lightning are uncommon.

The natural vegetation in this rainy climate is heavy forest—coniferous or broad-leaved evergreen. In certain localities, perhaps because of rather poor drainage, a thick mat of grass takes the place of forest; in other places, where the rainfall is somewhat less than the average for this climate, or where the soils are pervious, deciduous forests (made up of beech, oak, maple, and the like) may be found. Logging and lumbering are important in several regions. Because of excessive rainfall and cloudiness and low summer temperature, this climate is not well suited to certain crops, although oats, rye, and potatoes do well, and many vegetables and bush fruits attain extraordinary size without sacrifice of flavor. The growing season is too cool and cloudy for corn and too rainy and cloudy for the most successful culture of wheat.[1] Pasturage, however, is excellent, and dairying flourishes in several regions possessing this climate.

[1] Where small grains are grown, special precautions must be taken in curing the harvested crop.

Although never too hot to make indoor work burdensome, at the same time this climate fosters out-of-door life nearly all year round. The less wet regions, particularly, are favorable to the mode of life practiced in occidental civilizations of the present time.

INTRODUCTION TO THE CONTINENTAL TYPES OF CLIMATE

Continental types of climate are several in number, and their individual features will be considered separately. In general they are characterized by (*a*) marked contrasts in temperature from season to season, and (*b*) great variability of weather from day to day. They are found especially well developed in the interiors of North America and Eurasia, and their peculiarities are due partly to the rapidity with which land masses become heated and lose their heat, from season to season, as compared with the oceans, and partly to the influence of cyclonic storms.

Land masses tend to be more extreme than sea expanses in seasonal temperature range. Continental interiors, therefore, are likely to have greater range in temperature than the sea borders of the continents. Similarly, of two regions near the sea, one with winds frequently or predominantly from the interior of a continent nearly always has a greater seasonal range of temperature than one with winds frequently or predominantly from the sea. The continental and the marine influence on temperature are marked in all latitudes, but it is in the middle latitudes and the lower high latitudes that they are most strikingly displayed.

THE HUMID CONTINENTAL TYPE OF CLIMATE WITH LONG SUMMERS

Inconstancy is the keynote of the humid continental climate with long summers. The annual range of temperature is wide. In the summer it may be as hot as the low latitudes for days or even weeks at a time; temperatures of more than 100° F. are not uncommon.

In winter there are periods—days or weeks in length—during which the cold is as intense as that of high latitudes; temperatures below −20° F. are recorded in extreme winters. Moreover, changes of weather are sudden and decided. A fall of temperature amounting to 30° F. may take place within an hour. A fall of 60° within a twenty-four-hour period, and a rise of 48°, have been recorded at Chicago. It is estimated by officials of the United States Weather Bureau that six or eight abrupt changes occur in the Great Lakes region (in the heart of the humid continental climate) to two in Tennessee (near its equatorward border) and to one along the South Atlantic and Gulf coasts of the United States. In contrast to the wide range in temperature between summer and winter, and the marked changes accompanying "spells" of weather, the normal daily range in temperature is not large, particularly in summer.

The average frost-free season, i.e., the growing season, is five or six months long, the length depending somewhat upon latitude. The dates of last frost in spring and first frost in autumn vary from year to year over a period of several weeks.

The annual precipitation is not heavy, but it is sufficient for a thriving agriculture. Nearly everywhere more falls in summer than in winter, although the total amount differs a great deal from place to place. Indeed, it would not be amiss to recognize within this type of climate a wetter and a drier phase. In any given place the precipitation is relatively constant in distribution from year to year; deviation of more than 6 or 8 inches from normal is rare, at least in the United States. Nevertheless, unseasonable periods of drouth or drenching may occur at any time. In an average year, about one-third of the days are rainy, another third cloudy, and the remaining third clear. Most of the winter precipitation takes the form of snow, which steals down from low gray clouds. Nevertheless, rain is likely to fall in every month, and in the southern margins of this climate as much as half the winter precipitation may come as rain. Now and then a snowfall turns into a drizzle of rain. On the other hand, some snows are driven down by merciless gales that become colder as they increase in force. These "blizzards," as they are called, may come several times a winter, or they may skip a season or two.

Some of the summer rain falls in prolonged drizzles, and some in swift thunder showers. Thunderstorms vary widely in duration, intensity, and destructiveness, but their occurrence several times a summer makes more or less damage inevitable in the course of a

season. In all, there are thirty to forty days a year with thunderstorms in the part of the United States having this type of climate.

The winds of the humid continental climate with long summers are extremely variable, both in direction and in velocity. Quite characteristically the compass is boxed once or twice a week. Some air is stirring nearly all the time. Dead calms do occur, but they rarely last more than a few hours, and often only a few minutes. The variability is roughly rhythmic, the tempo being faster and more marked in winter than in summer. The most violent manifestation of this variability is the tornado, occurring both in Russia and in the United States, but particularly in the latter.

The natural vegetation of the humid continental climate with long summers varies from open grassland of the prairie type in the drier sections to deciduous forest of oak, hickory, beech, and maple in the sections with more rain. In places there are mixed forests of deciduous trees and evergreen conifers, or even considerable stands of conifers alone. The broad-leaved trees, such as oak and maple, are deciduous because of the cold season.[1]

Almost any crop that does not require more than six months frost-free season may be grown in this type of climate. Of such crops, corn (maize) and certain of the grain sorghums are of paramount importance. Of the grassy cereals, millet, oats, rye, wheat, and barley are raised in quantity. Some of these are sown in the autumn, others in the spring. Forage crops of importance include timothy, clover, alfalfa, and the native prairie grasses.

Except in the equatorward margins of this climate the summers are somewhat too short for the successful growth of rice and cotton, and the winters too cold for tea and mulberry. Pastures may be used for grazing live stock, but the cold, snowy winters and the tendency to drouth in late summer subordinate this industry to tillage. Agriculture therefore is predominantly of the "mixed farming" type. In this regimen the farmer tills a variety of cereals, some of which are fed to animals, he maintains pasture land for grazing, he raises enough vegetables and fruits for his family, he milks a few cows, and he sells off grain, stock, dairy products, potatoes, and fruits which are not needed for home consumption. In the "drier phase" of this type of climate, on the borders of the semi-arid regions, the drouth hazard in agriculture is considerable.

[1] Cf. the deciduous trees of the wet-and-dry low latitude climate, which drop their leaves in the *dry* season.

The frequent changes of weather make this climate stimulating to human activity, but many periods are uncomfortably hot, cold, wet, or dry.

THE HUMID CONTINENTAL TYPE OF CLIMATE WITH SHORT SUMMERS

This climate resembles the humid continental type with long summers, but there is enough difference to make human activities measurably unlike in the two types.

Thus the average temperatures are enough lower in the more northerly type to confine the growing season to some four months. Hot spells during the summer may equal in intensity those of the long-summer climate, but they are likely to be of shorter duration; on the other hand, cold waves in winter generally last longer, and temperature is likely to fall to −40° F. in many places. Corn will not mature in the short growing season with relatively few and brief periods of hot weather and fall-sown grain is winter-killed. The winters necessitate well-built dwellings, heavy clothing, heat-giving food, and much artificial heat.

As in the long-summer climate, so in the short-summer type the precipitation is distributed throughout the year, with a maximum in summer, but the total amount is everywhere less. This does not affect crops adversely, however, because the lower temperature means less evaporation, and correspondingly greater availability for use by plants of a given amount of rain. Furthermore, the percentage that falls in the early summer—at the peak of the growing season—is higher than in the long-summer type. Nearly all the winter precipitation takes the form of snow, and although the total fall is not great, the winter's accumulation is likely to hamper travel, because there is little melting until the end of the season. Sensible temperature in winter is not so low as might be expected, because the air is relatively dry; hence long periods of very low actual temperature do not occasion as acute discomfort as might be expected.

Storms are of the types described as characteristic of the humid continental climate with long summers, except that tornadoes are rare. There are fewer thunderstorms in the average year, and possibly blizzards are more numerous. The succession of bright and dull spells of weather is perhaps a bit more regular.

The natural vegetation varies from place to place, just as in the long-summer type. In the drier margins are prairies of waving grasses; in the wetter regions forest predominates. But in contrast to the deciduous or mixed forests farther south the stand in the short-summer climate is almost purely coniferous. In some of the forested areas logging and the trapping of fur-bearing animals are leading industries. The major cultivated crops include wheat, barley, rye, and flax for seed or fiber. All these, save rye, must be spring-sown, in contrast to the practice usual to the regions having a less severe winter. Corn is grown for ensilage only.

The forbidding cold season delayed the development of regions having this type of climate until modern times—indeed, everywhere except in Central Europe until toward the end of the nineteenth century. Consequently the full possibilities of the climate have not yet been plumbed. Probably farming will be the chief occupation of the inhabitants, when the geographic adjustment called for by present economic conditions is perfected.

A MIDDLE WEST BLIZZARD

The following paragraphs describe a blizzard in Northern Iowa.

"One such storm which leaped upon us at the close of a warm and beautiful day in February lasted for two days and three nights, making life on the open prairie impossible even to the strongest man. The thermometer fell to thirty degrees below zero and the snow-laden air moving at a rate of eighty miles an hour pressed upon the walls of our house with giant power. The sky of noon was darkened, so that we moved in a pallid half-light, and the windows thick with frost shut us in as if with gray shrouds.

"Hour after hour those winds and snows in furious battle, howled and roared and whistled around our frail shelter, slashing at the windows and piping on the chimney, till it seemed as if the Lord Sun had been wholly blotted out and that the world would never again be warm. Twice each day my father made a desperate sally toward the stable to feed the imprisoned cows and horses or to replenish our fuel. . . . .

"So long and so continuously did those immitigable winds howl in our ears that their tumult persisted, in imagination, when on the

third morning, we thawed holes in the thickened rim of the window panes and looked forth on a world silent as a marble sea and flaming with sunlight. My own relief was mingled with surprise—surprise to find the landscape so unchanged. True, the yard was piled high with drifts and the barns were almost lost to view, but the far fields and the dark lines of Burr Oak Grove remained unchanged.

"We met our school-mates that day, like survivors of shipwreck, and for many days we listened to gruesome stories of disaster, tales of stages frozen deep in snow with all their passengers sitting in their seats, and of herders with their silent flocks around them, lying stark as granite among the hazel bushes in which they had sought shelter. It was long before we shook off the awe with which this tempest filled our hearts."[1]

WINTER OPERATION OF RAILROADS IN THE NORTHERN PART OF THE LOWER PENINSULA OF MICHIGAN[2]

"Winter railroad operation in Michigan presents some problems that are little understood and yet which finally enter into the cost of transportation. One section of railroad may often be operated more economically than another of equal mileage in a different part of the country.

"This is shown by the experience of the Michigan railroads during the winter just closed (1921–22). Few persons realize, particularly those of the southern counties of Michigan, the problems which beset the transportation industry as a result of snow and sleet storms. Nine men out of ten in the southern section will talk volubly about the "open winter," unmindful of the hardships that occurred not a hundred miles farther north. As a matter of fact, the Pere Marquette Railway went through one of the most trying seasons in its history in the winter which has just closed. The snow plows were in service on the Grand Rapids-Petoskey division from the middle of December until nearly the end of March, and trains had to be operated with a low tonnage

[1] Hamlin Garland, *A Son of the Middle Border*, pp. 110–111. New York: Macmillan, 1923. (Copyrighted by The Macmillan Company. Reprinted by permission.)

[2] Quoted, with omissions, from *Pere Marquette Service* (April, 1922), VII, No. 10, pp. 1–2.

rating. This was likewise true of parts of two other divisions. For a part of the time, to be exact from the middle of December until February 15, the plow was kept in action each Sunday. From February 15 on it was necessary to run it twice a week to keep the lines clear. This, in itself, is a costly operation which places the northern lines at a disadvantage as against those in the south when relative earnings are under consideration.

"The storm of February 22 in particular resulted in unusual expenses, loss of earnings, payment of per diem on foreign cars detained on the line, and otherwise presented some hardships to the railway and to its employees. At 7:00 A.M. Superintendent J. A. Anderson of the Chicago-Petoskey division received word that the telegraph and telephone lines were down between Romona and Otia. The northbound Train No. 1 was accordingly held at White Cloud because there were no means of communicating with the crew of Train No. 4, a superior train, southbound. In the meantime, No. 4 did not leave Traverse City until 11:00 A.M., five hours after its scheduled departure, because a snow plow had to be run ahead as far as Baldwin. A motor car which had left Grand Rapids as soon as the advice about the disruption in communication was received proceeded as far as Bitely conveying the staff officers who were to supervise train operation from that point. At 4:00 o'clock that afternoon, word was received that the telegraph wires were down from a point just north of Bitely as far as Brethren. In some cases trees had fallen across the wires and caused serious damage. This was also true of the wires from Kaleva to a point north of Thompsonville. Maintenance of way men and others were pressed into service to clear the line, and it was necessary to pick the ice off the rails for a distance of 46 miles. The last train operated into Traverse City reached there on Wednesday, February 24, and then the lines were completely closed until February 27. Meanwhile, the line from Traverse City north to Petoskey was completely blocked, and it remained so for 12 days, the first train running in and out of Petoskey on March 3.

"Some of the trainmen who had experience in France as members of the American Expeditionary forces and who were engaged in clearing off the tracks, compared the damage done to the havoc caused by the enemy guns in the battle of the Argonne in the World War. The trees snapped off under the weight of the ice and snow, leaving a stub cut off as clear as if it had been done with heavy artillery. Ordinary weeds were encased in a coating of ice two to four inches in thickness.

Wires were torn down under their load of ice and snow, and the rails over every bridge necessitated being cleared off with a pick.

"The difficulties experienced on the Chicago-Petoskey lines made themselves felt on certain parts of the Toledo-Ludington and Port Huron-Grand Rapids division.

"What is true of the February storm applied largely to the storm which came in March, although it was not accompanied by sleet, but it paralyzed business, nevertheless."

TYPES OF THUNDERSTORMS

Thunderstorms are noteworthy features of the continental types of climate. Often toward the middle of a muggy summer afternoon, fleecy, white clouds begin to pile up on the horizon. Rapidly they grow, coalesce, and darken, to form an opaque leaden background, before which strong winds in the upper air drive fragments of darker cloud. The surface air, which has been oppressive, lightens, the gusty wind swirls funnels of dust along roads and across plowed fields, and air currents bring from aloft an invigorating coolness. Then comes a brief calm. Then the twilight is riven by flames of lightning which are answered by roars of thunder, and the earth is deluged with beating rain. The wind, momentarily stilled, gathers intensity, screeches through the treetops, and drives the heavy rain, now from this quarter, now from that. The intermittent play of lightning intensifies the darkness; the incessant crashing of thunder exaggerates the tumult of the gale. Presently the sky brightens, the din subsides, the lightning dies away in a distant flickering, the rain ceases, and the descending sun casts a mellow glory over the fresh, washed earth. The storm has lasted only twenty or thirty minutes, but it may require days to clean up débris torn from trees, to dry out interiors unwarily left open by absent householders, to restring fallen electric wires, and to repair electric generating stations put out of commission by strokes of lightning. Moreover, every severe thunderstorm takes its toll of human life, burned buildings, and irremediable soil wash.

Not all thunder showers occur on summer afternoons. At any time of day or night, except in winter, some hours (perhaps a day) of gray skies, light, shifting breezes, and oppressive air may be succeeded by increasing darkness accentuated by lightning on the horizon.

Rapidly the flashes approach and sharpen. Quietly rain begins to fall, but in a moment violent puffs of wind drive the increasing downpour this way and that. Soon the storm is in full cry. When it abates it gives place to another season of gray, dispiriting weather. Often three or four such storms occur in as many days, interspersed with cloudy weather or light drizzles. Such a period of rains is likely to be closed with a "clearing" thunder shower, after which the sun begins its task of drying out a sodden world. Thunder occasionally accompanies similar stormy periods in winter, but squally weather is rare at that season.

TORNADOES

"A tornado, frequently misnamed a cyclone, is the most spectacular of all storms known to inland America, and especially so in the prairie States, where the characteristic cloud can be plainly seen for miles. Its almost irresistible force is so terrifying and the damage and curious results of the enormous velocity of the whirling wind and sudden drop in pressure in the center of the vortex are so impressive that, once seen, they are never forgotten. Well-built houses explode and are carried away in small pieces, and stately shade trees that have sheltered families for generations are uprooted or have their limbs twisted off short as the whirling, writhing cloud descends from the sky and strikes them in its path, and yet perhaps a frail shanty within a few feet will escape without a board missing.

"To the early settlers of Kansas, coming as they did from distant eastern States where such phenomena are almost unknown, these storms were one of the wonders of a new country to be told over and over to visitors and sent as special items of news to papers that gave them wide publicity. The result has been that the expression, 'Kansas cyclone,' has almost become an idiom of the language and the reputation of the State for visitations of these storms is greater than that of any other part of the country when, as a matter of fact, there is no reason to believe in the light of available data they are more numerous here, area considered, than in other States in this part of the country.

"During the 33 years for which records of tornadoes in Kansas are available 302 have been reported and of these only 9 per cent have

occurred in the western third of the State, 41 per cent in the middle third, and 50 per cent in the eastern third. . . . .

"Tornadoes have occurred in the State every month of the year, except January and December, but are most liable to occur in the late spring and early summer, since 50 per cent of the total number on record have been reported in May and June. Usually they come in the late afternoon, but they have been reported at practically all hours of the day.

"The meteorological conditions that precede a tornado are so well known that the term, 'cyclone weather,' has become a rather common expression in the State and refers to the oppressively warm, humid, or 'sticky' weather that usually precedes them by several hours. . . . .

"They may form after several hours of light wind or during a violent thunderstorm. Persons who have witnessed their formation usually report a great commotion in a threatening cloud or more commonly 'two clouds came together.' From this whirling mass the characteristic cloud descends until, in the case of the damaging storms, it touches the earth. Sometimes this cloud is really funnel shaped, more commonly it is described as resembling an elephant's trunk or a gigantic snake as it writhes and sways back and forth in its progress. Other observers have stated that it reminded them of a rope swinging back and forth from the clouds. Usually in case of a slender cloud the color is a milky white, except that near the ground it is dark from flying dust and débris. Clouds of larger diameter are generally of much darker shade.

"It is not uncommon for two or more of these pendant clouds to be in evidence at the same time, sometimes in the formative stage, and as many as eight have been reported. Often two will combine to form one of greater violence.

"The noise of one of these storms as it approaches is terrific and has often been described as being 'like that of a thousand railway trains crossing a trestle at the same time.' It is probable the immense amount of destruction accomplished almost instantly as the whirling cloud passes over objects accounts for a great deal of this noise. Some observers have reported a peculiar humming noise like that of rapidly revolving machinery.

"These storms cross the country at the rate of about 40 miles an hour, usually from the southwest, but there is no certainty about this. Occasionally one has been known to turn almost at right angles to its

original course and an instance has been reported where one moved back over the same path it had just traveled.

"In an open country, which is characteristic of most of Kansas, a tornado cloud can be seen for miles and there is generally opportunity to take refuge when it occurs in the daytime. The most common and effective shelter is the far-famed 'cyclone cellar,' which is a cave near a residence, partially underground, with its top covered with soil and commonly used for dairy products and storing fruits and vegetables. Next in frequency of use for refuge is the southwest corner of the cellar or basement of a frame house. There are elements of danger in this, however, as, should the house be blown away, the cellar is likely to be partially filled with débris blown in with great violence. Instances have been reported where persons have survived by lying down in a ditch or shallow excavation, or simply on the lee side of a tree and locking the arms about it. In all these cases there is danger from flying pieces of timber or other objects with which the air is generally filled during such a storm; also a tree is likely to be uprooted if it is near the center of a storm path.

"The freakish occurrences that result from these storms will tax the credulity of a person who has never seen them. Undoubtedly there is the usual tendency to exaggerate them, but after examining the wreckage a person is inclined to believe almost any story that is told. The often-recited instances of straws being blown with such violence that they are left sticking in the bark and even in the wood of a tree or fence post have to be seen in order to be appreciated. Chickens are sometimes stripped of their feathers and left alive, though more often they are killed if near enough the vortex of the cloud for that to happen. An instance has been related on creditable authority of a dresser being smashed to kindling and its mirror carried some distance and set down against a fence without being cracked; also of a window sash being blown from a railway depot, which was demolished, and laid down on an adjoining lawn with a heavy iron scale weight on it without the glass being broken. A glass jar of fruit from a shelf in this same depot was blown a considerable distance and picked up later in perfect condition. The writer has known of an instance where a well-built schoolhouse was torn into small pieces and large elm trees about it uprooted, yet a small coal shed among the trees and a short distance from the schoolhouse escaped with only one board missing. It is interesting to note that several people who had vainly tried to

get into the schoolhouse for shelter from the storm had taken refuge in this coal shed and escaped uninjured. One of the remarkable features noted in reading over the accounts of these storms is the number of almost miraculous escapes. Unexplainable and almost unbelievable occurrences similar to the above that have come to the attention of the writer might be repeated at great length.

"Tornado paths seem to be almost entirely independent of the topography of a country, popular opinion to the contrary notwithstanding. It is often said of a town which has never been visited by one that it owes its immunity to being in a valley, but the tornado of June 5, 1917, crossed the Kansas River Valley a few miles above Topeka, mowing down trees on the steep slope of the high bluff as it descended into the south side of the valley and demolishing the little town of Elmot, which is on the lee side of a high bluff in the valley of Halfcreek.

"Lightning is sometimes erroneously said never to strike twice in the same place, but this is certainly not true of a tornado. The little town of Codell, in Rooks County, Kansas . . . . was struck by a tornado on May 25 for three years in succession, each storm coming at approximately the same hour of the day.

"It is not at all unusual to find persons in Kansas who have been eyewitnesses of tornadoes, but photographs of the cloud are exceedingly rare. Usually one is so absorbed in watching the unusual sight or in getting to a place of safety that a camera is not thought of until it is too late."[1]

The following description of a tornado which passed over Sherman, Texas, in May, 1896, is unusually graphic.

"When the cloud passed in front of me it seemed to be going at the speed of a galloping horse. The speed was not so great but that almost any one running to the east or to the west could have got out of the way. The cloud swelled out above the ground, but the top of it was higher than the sides. It seemed to be churning up all that it touched and throwing out the fragments at the top. At the same time, as it moved along, the mass had a rotary motion. It whirled round and round in a direction from right over to left. Only the outlines of the mass could be distinguished. It was impossible to see into it. Houses and other things went up as the cloud reached them, disappearing in the revolving interior. At the top and around the edges I

[1] S. D. Flora, "Kansas Tornadoes," *Monthly Weather Review*, XLVII (1919) pp. 447–448. Washington: U.S. Weather Bureau, 1919.

could see things whirling and then falling as they got beyond the edges. The revolving velocity was so great [that] it set the adjacent air in motion, and the lighter things, such as leaves and twigs, and bits of pine and particles of mud, circled far outside of the cloud and fell at considerable distances from the path of the cyclone."[1]

COMPARATIVE AVERAGE CLIMATIC DATA FOR WINNIPEG, MANITOBA; OMAHA, NEBRASKA; COLUMBUS, OHIO; PORTLAND, MAINE

	Winnipeg	Omaha	Columbus	Portland
January temperature	−4° F.	21° F.	29° F.	22° F.
July temperature	66° F.	77° F.	75° F.	68° F.
Date of first killing frost in autumn	Sept. 15	Oct. 13	Oct. 17	Oct. 18
Date of last killing frost in spring	June 1	April 26	April 16	May 14
Annual precipitation	20.2 inches	30.5 inches	36.7 inches	42.6 inches
Annual snowfall (included in "precipitation")	48.7 inches	25.7 inches	23.0 inches	74.3 inches
January precipitation	0.8 inches	0.6 inches	3.0 inches	3.8 inches
July precipitation	3.3 inches	4.4 inches	3.7 inches	3.5 inches

THE CLIMATE OF EAST MARGINS OF CONTINENTS IN HIGHER MIDDLE LATITUDES, OR THE MODIFIED HUMID CONTINENTAL TYPE OF CLIMATE

This type of climate is a modification of the humid continental, resulting from proximity to the ocean. The range of temperature from season to season is slightly less than in continental interiors in the same latitudes. The winters are almost as cold, but the summers are distinctly less hot. Spring usually is late, and the maximum temperature of summer lags a month behind the true continental type. Conversely, the autumn frosts are delayed and the coldest winter month is February.

[1] Quoted, with slight omissions, from A. J. Henry, *Monthly Weather Review*, XXIV (1896), p. 81. Washington: U.S. Weather Bureau, 1897.

Rainfall is considerably heavier than in continental interiors. In winter, when the precipitation generally takes the form of snow, this is particularly noticeable. Frequently great drifts partially bury occupied buildings, roads are blocked, and cities are compelled to spend large sums of money to clear the streets. In Northern New England farm buildings commonly are connected with one another and with the house, by covered sheds. Remote sections may be reduced for weeks to snow-shoe communication with the outside world.[1] Cloudiness is common at all seasons. Sensible temperature is quite as low in winter and as high in summer as in the continental interiors, although actual winter and summer temperatures are less extreme.

Weather changes are frequent. When the winds are easterly they bring in quantities of damp air from the ocean, causing periods of raw, chilly weather in winter, and cool, refreshing weather in summer. Thunderstorms are not uncommon, but the greater part of the rain is precipitated in gentle showers, unaccompanied by lightning. Tornadoes rarely occur, and the continental blizzard does not visit regions having this type of climate, although it has its counterpart in the "Northeasters," which combine heavy snowfall with low sensible temperature.

The natural vegetation is much like that of the more humid parts of the humid continental climate with short summers, i.e., coniferous forests, with a sprinkling of deciduous, broad-leaved trees in the southern margins.

Cultivation is more narrowly limited than in the humid continental climates, by the comparative coolness and cloudiness of the growing season. Corn and wheat, the prime staples of the humid interiors of continents, cannot be grown satisfactorily. Their place is taken by oats and rye. Potatoes and fruits are important locally. In many districts the land, left in pastures, is devoted to the rearing of live stock. In such places dairying is likely to be a thriving industry.

For year-round habitation this climate is unpleasant, but it is highly prized for summer resorts.

[1] Whittier's "Snow Bound" describes such a winter in New England.

THE CONTINENTAL AND THE MARINE INFLUENCE IN CLIMATE

The fundamental reason for the difference in seasonal range of temperature between continental and marine climates is that land heats up and cools off more rapidly than water. Land surface heats more rapidly than water for several reasons: (*a*) its specific heat is lower, with the result that a given quantity of heat raises its temperature more than it does that of water; (*b*) it is a poor reflector of heat, as compared with water, hence more of the heat that strikes a land area is absorbed than is the case with a water area; (*c*) it is essentially opaque, and heating therefore is confined to the upper layer, whereas water is transparent and heating takes place in lower as well as upper layers; (*d*) the surface layer of the land is not moved and mixed with other layers, as may be the case with water, due to waves and currents; (*e*) ordinarily there is less evaporation from land surfaces than from water, and therefore less of the cooling induced by evaporation. Land surface cools more rapidly than water because (*a*) in losing a given quantity of heat into the atmosphere its temperature is lowered more, since its specific heat is lower; (*b*) land being opaque, loses heat almost altogether from a thin upper layer, whereas water, being transparent, loses heat from lower layers as well as upper, and the cooling of the surface of the land consequently is not retarded by heat coming from lower levels, as is the case with water; (*c*) in land there are not the convection currents that in water cause the surface layer to sink when somewhat cooled, thereupon being replaced by warmer subsurface layers, which in turn must be cooled.

CLIMATIC DATA FOR PORTLAND, MAINE, AND PORTLAND, OREGON

	Portland, Maine	Portland, Oregon
January temperature	22° F.	39° F.
July temperature	68° F.	67° F.
Date of first killing frost in autumn	Oct. 18	Nov. 16
Date of last killing frost in spring	May 14	March 16
Annual precipitation	42.6 inches	42.5 inches
Annual snowfall	74.3 inches	15.2 inches
January precipitation	3.8 inches	6.3 inches
July precipitation	3.5 inches	0.8 inches

THE MIDDLE LATITUDE DESERT TYPE OF CLIMATE

Middle latitude deserts, like low latitude deserts, have insufficient precipitation for the growth of crops without irrigation. Nevertheless, some rain falls each year in all regions having this type of climate. It comes, as a rule, in the form of thundershowers, erratic in distribution and infrequent at best. As a natural corollary to this type of rainfall, relative humidity is low, particularly in the daytime. As many as 75% or 80% of the days may be sunny. In Nevada, for instance, an average of 186 days a year are cloudless, 94 are partly cloudy, and 85 cloudy.

Wide seasonal range of temperature is characteristic of this as well as of other continental climates. Nearly every station where data have been kept holds records of more than 100° F. in both midsummer months, and the midwinter temperature occasionally falls below zero (F.). The diurnal range is wide also, particularly in summer.

Sagebrush, thorny plants, and scattered bunches of harsh grass give the desert landscape a gray-green appearance, when seen at a little distance. Close up, however, bare ground is seen to predominate. After the rare showers the country is bright with desert flowers. In the oases, most middle latitude crops can be raised under irrigation. The winter compels almost complete cessation of agricultural activities, in contrast to low latitude deserts, where the growing season is

continuous. This is the chief reason for distinguishing these two types of desert climate from each other.

The high value of irrigated land enforces intensive agriculture in the oases, and the practice of irrigation on a large scale creates patches of dense population in an otherwise almost tenantless waste. These settlements tend to develop social co-operation to a degree unknown among farming peoples in humid regions, for the group as a whole is absolutely dependent for its existence on the common irrigation works.

THE SEMI-ARID MIDDLE LATITUDE TYPE OF CLIMATE

The semi-arid climate in middle latitudes is intermediate in character between the arid and the humid types. In some years the amount of precipitation equals that of the humid continental climates, in other years it is as low as that of middle latitude deserts. In a number of ways this meager rainfall is favorably distributed. The maximum comes in late spring or early summer, just the season when the vegetation needs it most. About 25% of the annual total is scattered through the winter—enough to maintain almost unimpaired the nutritive value of the dry grasses. Finally, the winter precipitation comes mostly as snow which protects and nourishes the winter pasturage.

Regions lying in the semi-arid climate are grasslands, and nearly everywhere the native grasses grow in tufts, spaced a few inches or a few feet apart. Native trees grow only along the streams and on steep slopes which have a poleward exposure.

The distribution of rainfall is so erratic, and the amount so variable, that the methods of crop-raising practiced in humid regions cannot be relied upon. Nevertheless, there is enough precipitation to permit a little tillage by so-called "dry-farming methods." Dry farming involves such measures as the growing of drouth resistant crops and the practice of various special methods of cultivation that aim to conserve moisture. Wherever water is available, irrigation is employed and oasis settlements, similar to those of deserts, spring up.

Grazing is a more important occupation of dwellers in semi-arid regions than cultivation of the land. Normally it is necessary to move about during the year in order to find sufficient grass and water

for the animals; nomadic life, therefore, characterizes almost all semi-arid regions.

Only where dry-farming has been introduced or where irrigation works have been established have permanent settlements been made in semi-arid regions, and most of these are small. It is interesting to note that farmers in the dry country in most cases prefer to designate the regions in which they live as "semi-humid" rather than as "semi-arid."

The alternation of weather, which is so striking in other continental climates, likewise characterizes semi-arid regions. But here the skies are cloudless for long periods and relative humidity is low. Because of the dry air and sunniness, the semi-arid climate is considered especially healthful. Occasional blizzards or cold waves cause widespread death to stock grazing on the open ranges.

DRY-FARMING IN SEMI-ARID REGIONS

In parts of the earth where the rainfall is too slight or too erratic to produce crops under ordinary methods of tillage, and where water for irrigation is not available, it may be possible to raise crops by "dry-farming." This term is applied to the special agricultural practices directed toward maintaining moisture in the soil. Dry-farming is essential to successful crop-raising in all semi-arid climates, but it is also widely practiced on the dry margins of regions with humid climates, including the dry subtropical, to insure against occasional crop failure. Moreover, it permits a certain amount of tillage in some regions ordinarily classed as deserts.

One fundamental practice of dry-farming is deep plowing (6–10 inches), to increase the rate and depth of permeation by water. This is done immediately after harvest, so that any rains of autumn and winter will soak in. The plowed land also retards the drifting of snow in climates where a part of the precious precipitation falls in that form. If rains beat down and pack the soil, a second and even a third plowing may be necessary.

Another important dry-farming practice is the conservation of moisture by retarding or preventing evaporation from the soil. If unchecked, evaporation may amount to several times the precipitation, e.g., at Yuma, Arizona, it is 35.2 times as great, and even at

El Paso, Texas, and Lost River, Idaho, it is more than 8 times as great. Evaporation is most rapid when temperature is high, when relative humidity is low, and when a strong wind is blowing. The chief means of checking evaporation is by the maintenance of a layer of dust over the surface of the field. This is accomplished by frequently repeated dragging, harrowing, or hoeing, not only before the crop is planted, but also until it grows too high to permit the use of machinery. Capillary movement of water through dust is so slow that little or no moisture is brought to the surface, where alone evaporation can take place. Straw or litter sometimes is spread on the ground or plowed into the surface soil to aid in creating a suitable "dust mulch."

Still another dry-farming practice is clean fallowing in occasional years; this procedure permits rainfall to accumulate as moisture in the soil during the time no crop is being grown. The ratio of fallow years to crop years varies with the amount and distribution of rainfall. Where precipitation is low and falls during the off season, the land may have to lie idle two years out of three, but on the margins of humid climates, or where the rain falls in the growing season, one year out of four may be sufficient. While the land is lying fallow it is not abandoned, but is carefully and repeatedly tilled, to prevent the growth of weeds which would use up soil moisture.

A fourth dry-farming practice is the custom of sowing seeds thinly and planting them deeply, to prevent overtaxing the soil moisture. Only half as much seed is used for a given acreage as in humid regions. In many cases the seed is sown in furrows, which are gradually filled up as the plants grow, thus leaving the roots several inches below the level of the field.

Summer fallowing and thin planting imply large holdings, and it has been urged that the average dry-farm in the United States should contain from 160 to 200 acres. A farm of this size can be worked effectively by one man only if he uses horse-drawn or motor-propelled implements which provide seats. Moreover, the number of machines used is considerably greater than on an ordinary farm in humid regions. Special types of plows for deep plowing, a number of varieties of drags, harrows, and hoe-cultivators, listers for preparing furrows in which the seed is planted, and drill seeders to insure deep planting, are among the machines required.

The success of dry-farming in many areas is doubtful. Not only does the amount of rainfall fluctuate markedly in regions where

dry-farming is likely to be followed, but the effort and consequent cost of producing crops is much larger than in humid regions where ordinary farm methods are practiced.

LIFE OF THE NOMADIC KHIRGHIZ

The following paragraphs describe a primitive group of nomads in the semi-arid middle latitude climate.

"Some of the Khirghiz of Central Asia are wandering herdsmen, or pastoral nomads, who live in the great Tian Shan Plateau of Central Asia in summer, and descend to the valleys and the lowland plain in winter. Their furniture consists of little except bags, saddles, and quilts. They eat their meals with their fingers from the common dish while sitting cross-legged on the bare ground or on the woolen rugs which are almost the only goods that they manufacture. Often their diet for months consists of sour milk, cheese, and meat with almost no bread and no vegetables or fruit of any description.

"The plants that flourish in a climate such as that of the Khirghiz are limited. In the dry lowland plains there is a fairly good growth of short grass during the summer, but it is the thin grass of the steppes and not the rich verdure of the prairies. Where water is available for irrigation excellent crops can be grown, but such places are too rare to support any great number of people. As one passes from the treeless grassy steppes into the mountains a fringe of willow trees is often seen beside the streams, but there are no real forests until a height of perhaps 6,000 feet is reached, where the rainfall is sufficient for tree growth.

"Since grass is the chief resource the [Khirghiz] keep domestic animals such as sheep, cows, horses, or camels. Since each family needs many animals the grass in any one place is eaten up in a month or two. Hence the most practicable mode of life is pastoral nomadism. That is, the Khirghiz must keep animals, and drive them from pasture to pasture. In summer he is on the high plateaus among the mountains with his flocks and herds, but as winter approaches the animals must gradually be driven downward to the lowest valleys, and out upon the plains where hay has been stored and where relatively permanent camps are occupied for three or four months in mid-winter.

"Since the summers are too cold for gardens, vegetables are almost unknown. Meat, too, is by no means eaten regularly, as one might suppose. Some of the young animals that grow up each year must be kept to increase the flock, and replace those lost in storms or eaten by wolves. Most of the rest must be exchanged for flour, cloth, knives, or other necessities. Hence only a few can be eaten. Milk is the staple food. Part of it is made into butter or hard sour cheese, and kept for weeks or months. The rest is used at once, but not till it has become sour. The Khirghiz have learned that if milk is used in large quantities, it is much more healthful sour than fresh.

"To many a Khirghiz boy or girl bread is as much a luxury as is cake to a child in America. The flour must be brought long distances on horses or camels. The supply may be exhausted long before the summer stay in the mountains is over. A Khirghiz mother often takes great pains to stow her little store of bread where the children will not find it and be tempted to eat it without permission. As there is no fuel except dry grass or the dried dung of animals, and as stoves are too heavy to be easily transported, the bread is baked in thin sheets over open fires, or perhaps the dough is cut into cubes and boiled in fat like doughnuts.

"The clothing of the Khirghiz is fitted for life in the cool, damp mountains in summer and in the cold lowlands in winter. At all seasons both men and women wear thick padded gowns that shed the rain, and high boots for walking in the wet grass and among the cattle. Much of their clothing is made from the wool of their sheep and the skins of their animals. The men wear great caps of sheepskin with the wool on the outside, and everyone has a sheepskin coat made so that it can be worn with the wool in or out according to the weather. The women wear head coverings of cotton cloth from Russia. They wind long embroidered strips into head-dresses a foot high. Both men and women keep their hands warm and dry by means of sleeves that extend down a foot or so below the hands. It is amusing to watch them throw back their sleeves when they eat, or begin to work."[1]

[1] Quoted, with omissions, from Huntington and Cushing, *Principles of Human Geography*, pp. 12–16. New York: Wiley, 1921.

ARABLE LAND OF THE EARTH*

	Square Miles
Tropical and subtropical zones:	
Total land area	23,000,000
Land too arid for crops	8,000,000
Land with adequate rainfall	15,000,000
Probably one-third ultimately arable	5,000,000
Cultivated at present	1,200,000
Arable land in pasture	600,000
Potentially arable not used for crops or pasture	3,200,000
Temperate zones:	
Total land area	29,000,000
Land too dry for crops	7,600,000
Land too cold for crops	6,400,000
Land with adequate rainfall and heat	15,000,000
Probably one-third ultimately arable	5,000,000
Cultivated at present	2,500,000
Arable land in pasture	1,500,000
Potentially arable not used for crops or pasture	1,000,000

*O. E. Baker, "Land Utilization in the United States," *Geographical Review*, XIII p. 25. New York: American Geographical Society, 1923.

THE SIGNIFICANCE OF VARIABLE WEATHER IN THE MIDDLE LATITUDE TYPES OF CLIMATE

The middle latitudes seem to offer greater advantages for advanced and complex types of civilization than either the low or the high latitudes. Most of the world's important civilizations have developed in the middle latitudes, and all leading nations of the present day are to be found there. Variability of weather during short periods and from season to season is favorable to health and stimulating to activity, and may be responsible in large measure for the energy and activities of the inhabitants of the middle latitudes.[1] The fact that nearly all the world's great cities are in the middle latitudes and that commerce and manufacturing, as well as agriculture, are most highly developed there, is suggestive of extremely favorable life-conditions.

[1] For a discussion of these points see: Ellsworth Huntington, *Civilization and Climate*. New Haven: Yale University Press, 1915; Ellsworth Huntington, *World Power and Evolution*. New Haven: Yale University Press, 1919.

HOURLY WIND RECORD AT UNIVERSITY OF CHICAGO OBSERVATORY, APRIL 23–26, 1921

April 23,	12:00– 1:00 A.M.	W
	1:00– 2:00	W
	2:00– 3:00	W
	3:00– 4:00	W
	4:00– 5:00	W
	5:00– 6:00	NW
	6:00– 7:00	W
	7:00– 8:00	W
	8:00– 9:00	NW
	9:00–10:00	NW
	10:00–11:00	W
	11:00–12:00	W
	12:00– 1:00 P.M.	W
	1:00– 2:00	W
	2:00– 3:00	W
	3:00– 4:00	SW
	4:00– 5:00	SW
	5:00– 6:00	SW
	6:00– 7:00	S
	7:00– 8:00	S
	8:00– 9:00	SE
	9:00–10:00	SE
	10:00–11:00	SE
	11:00–12:00 P.M.	SE

April 24,	12:00– 1:00 A.M.	SE
	1:00– 2:00	SE
	2:00– 3:00	S
	3:00– 4:00	S
	4:00– 5:00	S
	5:00– 6:00	S
	6:00– 7:00	SW
	7:00– 8:00	S
	8:00– 9:00	SW
	9:00–10:00	SW
	10:00–11:00	S
	11:00–12:00	S
	12:00– 1:00 P.M.	SW
	1:00– 2:00	SW
	2:00– 3:00	SW
	3:00– 4:00	S
	4:00– 5:00	S
	5:00– 6:00	S
	6:00– 7:00	S
	7:00– 8:00	S
	8:00– 9:00	S
	9:00–10:00	S
	10:00–11:00	S
	11:00–12:00 P.M.	SW

April 25,	12:00– 1:00 A.M.	S
	1:00– 2:00	S
	2:00– 3:00	S
	3:00– 4:00	S
	4:00– 5:00	SW
	5:00– 6:00	S
	6:00– 7:00	S
	7:00– 8:00	S
	8:00– 9:00	S
	9:00–10:00	S
	10:00–11:00	S
	11:00–12:00	SE
	12:00– 1:00 P.M.	SE
	1:00– 2:00	SE
	2:00– 3:00	SE
	3:00– 4:00	SE
	4:00– 5:00	SE
	5:00– 6:00	SE
	6:00– 7:00	SE
	7:00– 8:00	SE
	8:00– 9:00	SE
	9:00–10:00	SE
	10:00–11:00	SE
	11:00–12:00 P.M.	NW

April 26,	12:00– 1:00 A.M.	W
	1:00– 2:00	SW
	2:00– 3:00	SW
	3:00– 4:00	S
	4:00– 5:00	SE
	5:00– 6:00	SW
	6:00– 7:00	SW
	7:00– 8:00	SW
	8:00– 9:00	SW
	9:00–10:00	SW
	10:00–11:00	SW
	11:00–12:00	SW
	12:00– 1:00 P.M.	S
	1:00– 2:00	SE
	2:00– 3:00	SE
	3:00– 4:00	SE
	4:00– 5:00	SE
	5:00– 6:00	E
	6:00– 7:00	SE
	7:00– 8:00	SE
	8:00– 9:00	SE
	9:00–10:00	SE
	10:00–11:00	SE
	11:00–12:00 P.M.	S

SOME CONSEQUENCES OF WEATHER[1]

"The weather in some form or other affects every living creature. It has been the topic of universal conversation. It is the subject naturally mentioned in beginning a chat with a friend or stranger. It has been the foundation of endless jests and it has furnished a theme for countless poems. The sparkling air, the brilliant sunshine, the drifting feathery snow flakes, the pattering rain, have brought joy to millions and yet the angel of death rides in the trail of the icy blast. The same wind may bring to one the intensest joy and to another the deepest tragedy. The same rain which brings tears to the eyes of a maiden robbed of an expected outing may bring smiles to an agriculturist, who sees in it the promise of an abundant crop. The same snowstorm may bring joyous anticipation of sport to a youth and may bring death to an aged neighbor. The stakes depending on the changes of the weather are so vast, that those dependent on the turns of the wheel of chance at Monte Carlo seem as nothing in the balance. But a risk dependent on the weather is not a gamble. The gambler stakes his all from choice in pursuit of excitement or gain, while the man whose welfare depends on the turn of the weather is bound by thongs of necessity. As mankind must be fed, the farmer must sow his seed and watch the turn of the weather which brings him abundance or want. The manufacturer must send his goods from regions where power is procured easily to other regions more favorable for food production, and risk their loss by the destructive hurricane. The merchant must bring his products from places where they are most readily grown to those where they are most needed, and risk their loss by moisture, heat or cold. In the United States alone more than ten thousand million dollars are taken from the soil each year. Fortunately, nature never completely deprives the grower of needed moisture, but the total difference in value between the amount grown in a year of abundant rain and a year of deficient rain may easily be five hundred million dollars.

"The toll of sickness and premature death and of losses to business from a lack of adjustment to unexpected changes of weather is so vast that it staggers all computation. It is not strange that the subject of the weather has occupied so much of the thoughts of mankind. . . . .

[1] Henry Helm Clayton, *World Weather*, pp. vii–viii. New York: Macmillan, 1923. (Copyrighted by the Macmillan Company. Reprinted by permission.)

"The work of the meteorologist has a spiritual as well as a material value.

"In no other way has man been more haunted by degrading superstitions than in his interpretation of the signs of the sky and air.

"The shining crosses formed by the sunlight in the filmy cirrus clouds, the blood-red rain, the fiery sunsets, the reverberating thunder, the blinding flashes of lightning, the pulsating aurora filled him with untold terrors; his terrible losses from prolonged droughts led him to load the air with sound by the beating of tom toms and even at times to sacrifice human victims to appease the anger of the Rain God. Through scientific research, these things have now found their natural explanation and man has learned that the universe is governed by well-regulated laws and not by angry impulse. Religion is slowly becoming elevated to the higher plane of spiritual intercourse, and is freed from the meaningless rites to appease an angry god."

THE HOT, DRY SUMMER OF 1916 IN KANSAS[1]

"[An] outstanding [feature] of the weather for July, 1916, ... [was] the hot, dry weather experienced in much of the interior portions of the country during the last two decades of the month."[1]

"This was a month of drought and continued hot weather in all parts of Kansas. It was the fourth warmest July on record and the driest since the State-wide weather observations were begun in 1887. Records for dry weather were also broken at several stations . . . . where observations were begun more than 40 years ago. The average number of clear days for the State was the greatest on record for any month.

"The hot weather was practically continuous, with hardly a day with a maximum temperature of less than 90° at any station. In a great many places temperatures of 100° or higher occurred on from 8 to 12 days, though very few hot winds were reported and no record breaking high temperatures occurred on any individual days. In the

[1] P. C. Day, "General Summary of Weather Conditions," *Climatological Data of the United States by Sections* (1916), III, No. 5, p. 49. Washington: U.S. Weather Bureau, 1916.

eastern part of the State the weather was made more oppressive by the absence of the usual amount of wind movement.

"The month's precipitation was below normal at every station reporting and scarcely more than half the amount of the previous driest July. Approximately a tenth of the State received less than a measurable amount of moisture while only a small per cent had as much as an inch. No county received enough rain for its needs during the month.

"The dry weather was ideal for finishing wheat and oat harvest, thrashing, and making hay, but the corn crop was caught at its most critical period of growth, just as it was tasseling and beginning to ear, and it suffered serious damage. It was generally reported that it was damaged from 40 to 60 per cent by the end of the month, the greatest loss occurring on uplands and in fields that were not well cultivated. Pastures and the third crop of alfalfa practically stopped growing and truck patches dried up except where they were irrigated. Owing to the hardness of the ground but little headway was made with fall plowing."[1]

THE FLORIDA FREEZE OF 1894

The freeze which swept over Florida on December 27, 28, and 29, 1894, caused serious losses to the orange crop of the state.

". . . . On the 27th a cold wave began to be felt; this increased in severity until the 29th, on which date the lowest temperatures since the beginning of observations by the Weather Bureau were recorded. . . . . The temperature fell to 18° as far south as Titusville. This severe freeze practically destroyed nearly all that part of the orange crop remaining ungathered, estimated at about two or three millions of boxes, and did, it is feared, great damage to orange groves and fruit trees of all kinds. . . . . Killing frosts occurred at all stations. except at Key West."

". . . . The following extracts from the reports of observers are worthy of record:

"'Jacksonville, Fla.—27th, cold wave; temperature fell from 60, at 8 A.M. of 26th, to 36 at 8 A.M. of 27th; fresh to high west and north-

[1] S. D. F., *op. cit.*, p. 75.

west winds. 28th, cold wave continues; temperatures ranged from 27 to 38; at midnight of this date the temperature had fallen to 19.5, and was going down at the rate of about 1° an hour; from sunset to 10:30 P.M., ice three-quarters of an inch thick froze on a bucket of water on the office roof. 29th, the temperature fell to 14 about 7 A.M., the lowest point recorded since the station was established. . . . .

"'Titusville, Fla.—29th, the temperature fell rapidly during the night, minimum being 18.5, which is the lowest recorded at this station. . . . . At 8 A.M. the temperature was 20 and partly cloudy, with brisk northwest winds which kept up during the greater part of the day. Mean temperature, 26; a fall of 13° from the mean of yesterday, and 35° below the normal.

'"Tampa, Fla.—29th, weather last night was extremely cold, and this morning a minimum temperature of 18.9 [was] recorded. . . . . [All] vegetation is frozen. Ice to the thickness of from 1½ to 2 inches is general, and in several dwellings ice formed to the thickness of ½ an inch. . . . . 30th, freezing weather continued throughout the night, the minimum temperature at 8 A.M., 22.9. The temperature rose during the day to a maximum of 60.'"[1]

THE UNITED STATES WEATHER BUREAU[2]

"While the value of the bureau's reports and warnings to many interests is so obvious as scarcely to need more than the brief mention already given, there are numerous special applications of the information to individual pursuits and industries that might not have been suspected. An account of some of these may lead to an increased use of the data in quarters where the possibility of their application has not yet been recognized, and additional details of the manner in which the information is utilized in a number of enterprises will doubtless be found of interest.

"The railway and transportation companies make continued use of the forecasts in all of their shipments. Perishable products are protected against temperature extremes by icing or heating, as

[1] *Monthly Weather Review and Annual Summary*, XXII (1894), pp. 506, 494. Washington: U.S. Weather Bureau, 1895.

[2] Henry E. Williams, *The Weather Bureau*, pp. 37–52. Washington: U. S. Weather Bureau, 1916.

conditions may require. Oftentimes shipments of perishable goods are accelerated when it is found possible to carry them to their destination in advance of the expected unfavorable temperature conditions. When this can not be accomplished, goods en route are run into roundhouses for protection. An advance notice of a cold wave will also often hold up a contemplated shipment until after the freeze has passed, and if the cold is protracted the companies will refuse to receive consignments of goods likely to be injured by low temperatures. These precautions apply in some instances to prospective temperature changes within comparatively narrow limits. Bananas, for example, require very careful handling and must be kept at a temperature of 58° to 65° during shipment, as a temperature below 55° chills the fruit sufficiently to cause a deterioration in quality, while a temperature above 65° inside the car will produce overripening. As bananas generate heat rapidly after being placed in the car, the problem of maintaining the requisite temperature becomes a delicate one, involving careful ventilation and a study of actual and expected temperature conditions along the entire line of transit.

"Similar precautions, based on the information of the daily forecasts and supplemented by a study of the daily weather map, apply to shipments of vegetables, fruits, eggs, and other products liable to damage from extremes of temperature. On the other hand, most meats are best shipped in cold weather, although the use of refrigerator cars prevents loss, and the shipment of live hogs and cattle by freight is avoided, if possible, when a hot wave is expected. High temperatures are also hurtful to certain other shipments, especially of fish and oysters, so that the question of the proper amount of ice to be used is intimately connected with the forecasts issued by the bureau. The daily forecasts and the reports of general weather conditions likewise assist in determining the points to which many shipments of perishable articles are directed, in order to meet the irregular demands that are frequently dependent upon the kind of weather that prevails in a given section. The movement of eggs kept in storage, for instance, is largely regulated by temperature changes, the announcement of a cold wave being usually followed by brisker shipments from western supply districts to the eastern markets, in anticipation of a rise in prices. Temperature forecasts and cold-wave warnings are closely watched by brewers, wine makers, and manufacturers of soft drinks. Wine shipments are usually withheld until danger from cold is past, as a slight frosting causes the tartaric acid in wine to crystallize and pre-

cipitate. Many brewers hold their beer shipments when the distance to be traversed is more than 60 miles and a minimum temperature of 20° is anticipated.

"The uses made of temperature forecasts in the cities are more varied than is generally supposed. With notice of an approaching cold wave greenhouses are closed and boilers fired. Preparations are at once made by heating and lighting plants, whether gas, electric, steam, or hot water, to meet the increased demands that will follow. Fire plugs, exposed mains, and general plumbing are protected. Large stockyards drain their mains. Gasoline engines are drained. Work in concrete is stopped. Brewing companies take care of exposed ammonia condensers and water connections. Street railway companies arrange for more heat in their cars. Natural-gas companies turn a larger amount of gas into their lines to provide for increased consumption. Merchants curtail advertisements or direct attention largely to cold-weather articles. Oyster dealers lay in a larger stock. Coal dealers supply partial orders to all customers needing fuel, instead of full orders to a few, and thus serve all of their patrons. Ice factories reduce their output. The dredging of sand and gravel ceases, and iron ore piled up for shipment is placed in the holds of vessels to prevent the wet masses from freezing solid. Charity organizations prepare to meet increased demands for food and fuel, and thus minimize suffering among the poor.

"In the agricultural districts the frost and cold-wave warnings are invaluable to the trucker and fruit grower, especially in the spring when the tender vegetables are protected by covering with paper, cloth, or soil, and fruit is safeguarded by smudging, irrigation, or other methods designed to maintain the temperature above the danger point. In the fall these warnings are utilized in the cranberry regions by flooding the bogs until after the cold weather has passed or danger of frost is over. Many crops, such as beans and grapes, are saved by being picked in advance of the freeze, while tobacco and unmatured corn are cut at once upon advance notice of damaging cold weather. Potato digging is suspended and the dug potatoes removed from the field, and sugar cane is cut and windrowed upon receipt of such advices, immense savings having resulted in the sugar districts of Louisiana as a result of such action. The expected duration and severity of freezes govern operations in the ice harvest. If the cold is to be prolonged the icemen await the desired thickness, but otherwise the cutting will be hastened in order to secure the best possible returns

under the circumstances. Forecasts in spring are helpful in the maple-sugar industry, as the collection and boiling of the sap are more or less dependent upon the coming conditions. The temperature forecasts are also largely utilized by farmers in the killing of hogs, by sheepmen at lambing and shearing time, and by stockmen in general at critical seasons of the year.

"In the raisin-growing districts of California rain forecasts are of great value. The raisin crop while drying is extremely susceptible to injury from rain, and the warnings enable the producers to protect the fruit by stacking and covering the trays. The accuracy of the rain forecasts for this region and the system for their distribution have been so complete that practically no loss from this cause has occurred for years. Rain forecasts are also utilized in the large fruit-growing districts to enable picking in advance of rains, so that the fruit can be shipped dry. Vegetables dug in dry weather are also shipped in better condition than those upon which rain has fallen after they have been taken from the ground. Broom corn is liable to damage from rain if left in the field. Much saving has resulted from consulting the forecasts in alfalfa cutting, since the alfalfa hay can be baled in the field if dry, but if baled wet it will spoil. The same benefits derivable from rain forecasts apply to alfalfa cut for seed, since a heavy fall of rain upon the crop, after cutting, ruins its commercial value. Lime, cement, brick, drain tile, and sewer-pipe material all require protection from rain during the process of manufacture, and cement work must be protected from rain for 24 to 48 hours after the cement is laid.

"The rain forecasts are used by contractors in their roofing work. Photographic firms working on a large scale find them helpful in planning for panoramic views. City departments determine the number of teams needed in street sprinkling, railroad companies guard against washouts, and irrigation companies control the output of water by expected conditions of rainfall as given in the forecasts. Physicians use them in advice to patients suffering with tonsilitis or inflammation of the throat, nose, or ear, where it is expedient that the sufferer should be kept indoors. They are also used by dentists, many of whom make appointments for bright days and reserve their plate work for days with inclement weather. A knowledge of temperature and moisture conditions in advance is of assistance in blast-furnace operations in determining the quality of the output. Warnings of heavy snows are very valuable to railroads by enabling them to organize their snow-fighting equipment and to reduce the tonnage of

their freight and passenger trains, if considered necessary. They are also necessary on the great western ranches and plains, where the stock is hurried from the ranges to shelter upon notice of blizzards, northers, or heavy snows. Forecasts of bad weather, whether resulting from low temperatures, heavy rains, heavy snows, or a combination of these, are used in regulating advertising, in arranging for automobile or other outdoor trips, in providing for indoor work on the farms, and in guarding school children from exposure to the elements.

"Some special uses of the storm warnings are found in the measures adopted to protect property and crops subject to inundation from high tides or backwater blown up by the winds. In advance of a predicted storm, rice planters flood their crops to prevent the straw from being broken by the winds. Agents of marine insurance companies refrain from insuring cargoes after a storm has been predicted. Fishermen take steps to protect their boats and nets. Lumbermen make their standing booms secure and regulate their log towing. At lake ports vessels load hurriedly if they can get off 2 to 5 hours in advance of offshore winds; if snow is also expected, a start of 7 to 18 hours is necessary. Considering the cost of operating a vessel whether standing or moving, a day saved from idleness in the harbor means an appreciable saving in expense.

"Flood warnings are indispensable to all river industries, as well as to the operations carried on in the lowlands subject to inundation. Their issue is followed by the removal of cattle from bottom lands and by the saving of such crops as can be cut before the high water reaches the threatened district. Fore-knowledge of expected river stages is also of great advantage in determining whether or not it will be advisable to undertake farming operations in the regions subject to overflow. The warnings enable fishermen to remove their fishing gear from the water, so as to avoid damage from the driftwood and logs that are brought downstream by the rise, and to devote their energies to gathering this drift for sale.

"Along the river streets of many cities the basements of warehouses and other buildings are submerged at high water; accurate river forecasts enable the business men to postpone moving their goods to the upper floor until the last moment, and often prevent the needless expense of such a transfer in cases where it is known that the flood crest will be below the point at which their basement stock would be imperiled. The warnings enable dealers to save wood and ties piled along the river banks. High stages of water are frequently

utilized by coal barges, enabling the cargo to be run aground at a desirable point at flood height, and then unloaded at leisure after the river falls. Navigation companies utilize them in arranging for the transfer of their offices and landing places from lower to upper docks. A knowledge of slight rises is often of great value, as a small swell frequently permits large movements by water. Lumbermen cut much timber in the swamps and along the streams during low water, looking to the rises to carry out their logs; advance information of coming stages enables them to have everything in readiness to prosecute their work without loss of time when the favorable conditions arise. During rising water those in charge of locks, dams, and levees are alert to the need of strengthening and protecting the property under their care; exact forecasting guides their operations as to time, place, and amount of protection, or may save them from expending money and effort in protective measures that will not be required.

"During flood periods seiners and gill netters are guided by the river forecasts in determining what class of gear to use to obtain the best results, as different kinds are needed for different stages of water. Fishermen in the Columbia River claim that the water stage seems to have some effect on the entrance of salmon from the ocean, and that, by watching the river forecasts, a spurt in the run of fish can be predicted with a fair degree of accuracy. Forecasts of low river stages are not without considerable value to some interests. When the stage falls below a given height many water-power plants have their supply cut off; with ample notice, they can have their auxiliary steam plants ready for use, and thus continue their business without interruption. Dock building, pile driving, dredging, and repairing are largely done during low-water stages, previous notice of which enables engineers to arrange for such operations.

"Among the miscellaneous uses of the various classes of forecasts are their application to the manufacture of certain articles where slight changes in temperature, moisture, and other weather elements have been found to affect the quality of the product. This is true of certain stages in the manufacture of bluing, varnish, oils, cement, lime, bricks, paper, photographic supplies, chocolate candies, and some acids. They also serve usefully the plans of public amusement companies, excursion enterprises, awning companies, and those engaged in outdoor painting.

"The daily maps and bulletins and the general bulletins and reports containing statistical data are utilized in many ways by the public.

Grain and cotton brokers are guided largely by the forecasts in their operations, but need the daily report of current weather conditions as well in their business transactions while in a less degree the retailer and the small farmer can also use the same information to advantage. Data of atmospheric pressure are used in tests of boilers, radiators, and automobiles, and in studies of the amount of fuel required to drive engines under varying atmospheric pressures. Statistics of wind force and direction assist in the installation of water-supply systems to be operated by windmills, in determining the origin of fires resulting from flying sparks, the pressure to which large buildings will be subjected under stress of heavy storms, and the surface movement of lake waters in connection with the disposal of city sewage. The humidity records are used by silk and candy manufacturers, in tuberculosis investigations, and in studies of the loss of electric current in high-voltage transmission.

"Data regarding rainfall and snowfall are extremely useful in planning irrigation enterprises and selecting reservoir sites, and are studied in connection with the construction of waterworks, bridges, culverts, and sewers. River data are utilized by filtration plants in guiding their methods of chemically purifying the water used for drinking purposes, as the conditions of the raw-water supply as regards bacteria content and turbidity are greatly affected by the height of the river and the amount of rainfall. They are also necessary in studies of stream flow, dredging operations, the location of wharves, the construction of dams, and in practically every phase of bridge building, levee work, and general river improvement. Weather maps are used by business men generally, by aero clubs in studies for flights, and by school teachers in class instruction.

"The miscellaneous climatological data are used in medical and scientific studies of the relation of weather to diseases and other conditions of health, life, or human pursuits; by railroad companies in the adjustment of claims and demurrage charges; by homeseekers; by invalids in search of health resorts; by irrigation investigators; by contractors and builders in settling labor accounts; by merchants in studies of the relation of the weather to their daily sales; by gas and electric light companies in showing their customers the relation of their monthly bills to the varying hours of daylight at different seasons of the year; as adequate testimony in court proceedings; in dry-farming investigations; in studies of soil culture, practical agriculture, and the life and migration of insect pests; in plans for the development of

the arid regions; in the preparation of historical records; by bond and investment companies in determining the loan values of farm lands in newly opened countries; in short, in nearly every calling in which the weather plays any part.

"Many more uses of the warnings and reports might be cited, but those already given—all of which are taken from personal letters received at the central office of the Weather Bureau or at its field stations—will suffice to show the extent to which they are utilized by the public in the practical everyday affairs of life."

HIGH ALTITUDE CLIMATES IN THE MIDDLE LATITUDES

In contrast to most highlands in low latitudes, those in middle latitudes have a relatively sparse population, a part of which is migratory. The climate of middle latitude highlands is distinctly harsher than that of neighboring lowlands, the degree of rigor varying with altitude, latitude, and land forms.

Three types of middle latitude highland may be differentiated as to climate: (1) mountain slopes and shoulders of medium elevation; (2) plateaus of medium elevation; (3) high mountain tops.

Mountains of medium elevation in middle latitudes receive more precipitation than nearby lowlands. In regions of extremely humid climate, ranges and peaks are likely to be drenched with rain in summer and buried in snow in winter. Such is the case of the Cascades of North America, the Andes of Southern Chile, and the mountains of Japan, all of which are noted for dense forests of majestic trees, and for high peaks eternally capped with snow and ice. Even where the lowland climate is dry, mountains possess a distinctly humid type of climate. Examples are the Rockies and the Tian Shan, which lie in the interiors of large continents; the Sierra Nevada, between a desert and a lowland possessing the dry subtropical climate; the Caucasus and the Alps, which are much more humid than their surroundings. All these mountains have considerable timbered area, and many of the unforested areas have a luxuriant grass cover. The distribution of precipitation varies widely from place to place, increasing up to at least 10,000 feet, the maximum elevation for which accurate records have been made. Rain is likely to come in the form

of violent convection showers in summer, accompanied by fierce wind and vivid lightning. Winter snow-storms partake of the character of blizzards. In ocean-facing mountains huge drifts gather. For instance, in the Middle Sierra Nevadas 20 feet of snow may accumulate. Railroads traversing such mountains are compelled to erect and maintain costly snowsheds many miles in length. Relative humidity is low much of the time, especially in summer.

The temperature conditions of mountains likewise differ from those of adjacent lowlands. The average at all seasons is lower, and consequently the growing season is shorter. The intense heat of the sunshine is offset by the chill of night, which makes frost probable during eight or ten months of the year. At levels above 9,000 feet, frost is likely to occur each month, but the length of the frost-free season depends largely upon air drainage. Inclosed valleys may experience winter temperatures of 40° or 50° below zero (Fahrenheit), whereas slopes in the vicinity with free circulation of air can be planted to the hardier fruit trees, such as apple and pear. Since most of the arable land in mountain regions lies in valley bottoms, the agricultural possibilities are much reduced by the drainage of cold air to the lower levels. The contrast between sunshine and shade is almost as marked as in the highlands of low latitudes, and a fire is welcome at night, even in midsummer.

The short growing season and the abundant rain restrict crops to those which mature quickly and can stand moisture. Hardy fruits can be grown in favored spots, generally on south-facing slopes or at the mouths of large canyons. Vegetables, oats, and barley are staples, but grass and hay is the most suitable crop of all. As a consequence, the grazing of animals is likely to be an important industry in mountain regions, e.g., the Alps. Since the succulent grass is conducive to maximum milk-production, some mountain folk, notably the Swiss, have specialized on cattle and goats, the milk of which they convert into butter and cheese.

The uniform, cool weather, the snowy vistas, the restful forests, the vivid green meadows, all combine to attract tourists and vacationers from the hot lowlands during the summer. As a result, the leading business of many mountain districts is the summer-resort trade. In parts of Switzerland and the Adirondacks, resorts are kept open in winter, for the sake of the skating, skiing, snowshoeing, tobogganing, and sleighing.

Plateaus in middle latitudes share the temperature conditions

of mountains, but nearly all of them are dry. The winter climate is likely to be dry and cold, without severe cold waves; much of the time the sky is clear and a light wind may prevail for days on end. In summer the strong insolation may result in very high temperature with low relative humidity. In Western Colorado 100° F. and 25% r.h. is not infrequent on summer afternoons. Grazing is likely to be a mainstay of human life, cattle for beef and sheep for wool making up the herds and flocks. Crops generally are confined to the few irrigable spots.

Above the mountains and plateaus regularly inhabited, belts of tundra and permanent snow girdle the higher peaks, just as in the mountains of low latitudes. The grassy meadows may be used for summer pasturage all the way up to snow. The line of permanent ice and snow lies at about 8,000 feet in the Alps, and at approximately 7,000 in the Cascades; in the Rockies of the United States it lies higher (at about 13,000 feet), owing to the scantier precipitation.

THE AGRICULTURE OF MOUNTAIN VALLEYS

Mountain-valley agriculture the world over has certain characteristics in common, characteristics that result from the shorter and cooler growing season and the restricted area that can be cultivated in mountains, as compared with lowland plains. The short, cool summers limit crops to hardy plants which will mature in the brief season, and can stand light frosts. Thus, in valleys in the High Andes of Ecuador, the Swiss Alps, and the Rocky Mountains, oats, barley, potatoes, cabbages, and hay crops are typical. All of these crops mature in a relatively short growing season, and all of them are able to resist the cold and at times frosty nights of midsummer. The restricted area available for cultivation in mountain valleys results in small, irregularly shaped fields, on which relatively little machinery of the type used so extensively in plains regions can be employed profitably. Restricted area also leads to intensive cultivation in many mountain valleys. The altitude at which any particular crop combination is to be found differs with latitude, being highest at the Equator. In high latitude mountain regions there is practically no cultivation, even in the valleys.

THE LOWER HIGH LATITUDE TYPE OF CLIMATE

The high latitudes as a whole are regions of scanty population, and because of their climate they always will be thinly settled. Consequently their geographic importance is slight. Nevertheless, there are such great contrasts in climate from place to place within the high latitudes that a number of types must be distinguished.

The growing season in the lower high latitudes is only two to four months long, and during this period frost may occur any night. This precludes dependence upon any of the standard cereal crops, and confines agriculture to vegetables and hardy fruits. In spite of the brevity of the growing season, the days are warm and midsummer afternoons may be as hot as those in the middle latitude continental types of climate. Summer days are very long and summer nights correspondingly short. This ratio is reversed in winter, which is very cold. Verkhoyansk, Siberia, holds the world's record for extreme cold, with $-94°$ F. In a number of places in North-central Siberia the average annual range of temperature is 120° F.; the lower high latitude climate experiences a wider seasonal range of temperature than any other type on earth.

Precipitation is as scant as that of desert regions in lower latitudes, but evaporation also is low, so that the light precipitation suffices for plant growth. Sensible temperatures in winter, though low, are less extreme than the actual temperatures might suggest.

The regions possessing this type of climate are covered with coniferous forests. Thus far these extensive forest regions have been but little exploited. A wide poleward margin consists of small, stunted trees that probably never will have commercial value. Fur-bearing animals are numerous in the forests, and at present hunting and trapping are the chief economic interests of these regions. Reindeer grazing offers interesting possibilities in the transition zone where forest merges into tundra. As already stated, agriculture is unimportant but not entirely impossible in this climate. In favored locations hardy and quick-growing vegetables and fruits, such as cabbages, turnips, radishes, and strawberries, will ripen. In some years hardy cereals will mature.

THE SUBPOLAR OR TUNDRA TYPE OF CLIMATE

In the subpolar climate the winters are so long and the summers so short that one season's snow is barely melted before the accumulation of the next winter begins.

At the time of the winter solstice night is continuous for a season which varies in length with the latitude. Both preceding and following this period of continuous night there is a much longer period during which the short intervals of daylight commonly are rendered cheerless by low-hanging, dull clouds that completely obscure the sun. At the time of the summer solstice there is a brief season of continuous daylight, and a longer one during which the days are separated by twilight, rather than by night. Throughout this period it is never too dark to read ordinary print, even at midnight. In summer, as in winter, cloudy and cold spells are numerous and prolonged, but the occasional bright days are exhilarating—perhaps they seem the more brilliant on account of their gloomy setting. Sharp changes in the weather are the rule in summer. John Muir, in chronicling the weather in the Bering Sea for a period of six weeks ending July 31, records a month of constant cloudiness, broken only by occasional momentary glimpses of the sun, with some snow every day; then three sparkling, hot days, followed by one of cold rain, another partly cloudy, and then more snow; after this a week during which it was by turns cold and windy, rainy, clear, foggy, rainy, and sunny and calm. A notable aspect of this and other climates in the higher latitude is the paleness of the sky, which much of the time is a washed-out blue even when the sun shines.

In the tundra regions of the Arctic Ocean borders of North America and Eurasia the ground is frozen most of the year. During the short season of a few weeks when the surface layers thaw out, various quickly maturing plants, such as mosses, lichens, some flowering annuals, and certain shallow-rooted bushes, transform the aspect of the landscape. In this vegetation mosses and lichens predominate, forming a spongy mat about a foot thick, into which the pedestrain sinks at every step. Travel is so fatiguing that all communication, except that on streams and lakes, is suspended during the summer.

Birds are numerous in summer, and several species remain throughout the year. In winter the permanent residents are warmly feathered to the tips of their toes. The reindeer and caribou graze on the tundra vegetation all year round. In winter they nose away the snow in order to get at the mosses and lichens beneath.

Despite the abundance of natural vegetation, crops of commercial value cannot be grown, for the summers are too short and cool. Native animal life, particularly aquatic life, is surprisingly abundant, and it is from the sea that the very few people who live in these regions get most of their subsistence. The hunting of seals, walruses, whales, and birds, together with fishing, occupies a large part of the time of inhabitants of the Arctic regions. In certain places herds of reindeer are kept by the aborigines, who are nomads migrating from seaboard to interior and back in order to utilize these meager and scattered resources of sea and land.

In no type of climate are people's ways of living more closely adjusted to the peculiarities of the natural environment, and in none is more complete use made of the natural possibilities, but so completely are human energies engaged in the struggle for existence that civilization has advanced but slightly.

THE POLAR OR ICE-CAP TYPE OF CLIMATE

In this type of climate the temperature is below freezing most of the time. There is a practically perpetual snow or ice cover on both the land and the sea, which consumes much of the energy of the sun's rays. The ice caps are exceedingly stormy, and the combination of low temperatures and high winds makes penetration far into the polar climate hazardous in the extreme. Statements from Antarctic explorers, quoted below, bear this out.

"The surface winds at our winter quarters were either gentle northerly winds, whose speed seldom exceeded twelve miles an hour, or gentle winds from the south-south-east or south-east. If these latter winds become strongly developed they pass over into a definite blizzard. One of the rarest winds at Cape Royds was a north-westerly.

"On the southern journey it was noted that south-south-east winds predominated on the surface of the Great Barrier. These sometimes swung round to between south-south-west and west-south-west. The Southern Party experienced a violent south-south-east blizzard at a point just beyond latitude 88° South. . . . . There was much soft snow on this part of the plateau at an altitude of over 10,000 ft.

"On the journey of the Northern Party to the South Magnetic

Pole it was found that the chief winds on the coast, as well as on the high plateau, are from south-south-west to west, with occasional blizzard winds from the south-south-east and south-east.

"During the whole time of our residence in the Antarctic, from February 1908, till the beginning of March 1909 no rain whatever fell. The snow usually came with a blizzard. These blizzards blew from a general southerly direction, at Cape Royds they were mostly from the south-east. It is clear that the snow brought by the blizzards is in part drift snow, in part new falling snow. On several occasions we noticed that, whereas in the earlier part of the blizzard the snow was largely redistributed old snow in the form of drift, towards the end of a blizzard fresh new falling snow would be deposited. . . . . The temperature of the atmosphere invariably increased considerably from the beginning of a blizzard towards its end. This rise was very marked, for whereas the initial temperature, at the beginning of a blizzard, would be perhaps minus 30° Fahr., at the end of a blizzard, after a lapse of possibly twenty-four to thirty hours, the temperature would have risen to plus 12° or plus 15° Fahr.

"The lowest temperature we experienced was minus 57° Fahr., near White Island on the Great Ice Barrier, on August 14, 1908."[1]

Similar reports come from explorers of interior Greenland and the Arctic seas.

"The night of April 2d was fine until early morning when it clouded up, and when we got under way it was dark and threatening, with a biting wind right from the direction of the Pole, swinging later to the west. . . . .

"Thick and blowing from the north all night, and the same when we got under way the 4th. The diffused light made it very difficult to follow the nearly wind-obliterated trail. Frequent snow squalls from the north and west added annoyance. At noon it began to lighten and when we reached Henson's igloo, the wind had ceased and the sun was trying to shine.

"The wind and thick weather came on again during the night of the 4th and continued. We got under way at 3:30 A.M. and found following the trail very difficult in the diffused light, and possible only with constant attention and straining of the eyes. This was distinctly fatiguing, and added to the depressing effect of the weather, was a

[1] T. W. E. David, and Lieutenant Adams, "Meterology," in E. H. Shackleton, *The Heart of the Antarctic*, II, pp. 403–405. Philadelphia: Lippincott, and London: Heinemann, 1909.

strain which I made up my mind to avoid as much as possible in future by not traveling in thick weather except when compelled to.

"The wind and snow continued all night of the 6th and the forenoon of the 7th, then the sun broke through and showed that it was no longer snowing, though the wind continued unabated accompanied by a furious and blinding drift.

"The wind continued its infernal howling past the igloo and among the pinnacles of the rafter close by all night. I was so comfortable physically, however (barring my stumps which were always cold when I was not walking, and sometimes even then) that there was nothing to distract me from its hell-born music, or keep me from thinking of the unbearable delay. It seemed as if I had been here a month. The wind which had been a little south of true west swung more to the south, the drift was less dense, as if the bulk of the snow were packed, and I fancied there was less weight in the wind in the evening.

"April 10th was another miserable day. The wind not quite so violent, but still continuing with a heavy drift that made traveling out of the question.

"Temporarily at least I had got past chafing at the delay and simply longed for the cessation of the infernal music, and to see the bright sun glinting on the ice-fields again, as a thin-blooded invalid in winter longs for the soft breath of summer.

"Another day, the sixth of the interminable gale. Will it never end? The wind and drift continued with unabated violence. For some three hours to-day, I pushed, and butted, and at times almost crawled on hands and knees, back and forth across the small floe on which we are camped.

"This partly for exercise, partly because I could no longer keep quiet, partly from a desire to determine with certainty, whether, if I were made of sterner stuff, I might not be traveling. I am perfectly satisfied now. *No* party could travel in this gale, not because of the cold, though that is not slight, but because of the physical impossibility. To face the gale would quickly wear out the strongest man living, even if it were possible to expose the face directly for more than an instant to the cutting drift. I am also satisfied that the effect of the storm will not be to make the traveling (if it ever clears) worse; or to obliterate our trail from the 'big lead' here.

"At last the unprecedented gale abated, or at any rate temporarily suspended, enough for me to get things moving.

"After midnight the violence of the wind moderated, and in the

morning the sun was shining, though a considerable drift was still running, and a heavy bank of drift lay all around the horizon.

"Gradually this subsided, and I was able to get some meridian observations with the transit. The drift made the use of artificial horizon impracticable. These observations gave our latitude 85° 12′, and our longitude but slightly west of the ship at Sheridan.

"It was a day of April weather, reminding me very much of the ice cap; blue sky with delicate 'mare's tail' clouds, then banks of fog, flurries of snow, and blue sky again, with a continuous light W.S.W. wind carrying a low drift along the surface. For several hours there was a fog bank, probably caused by open leads.[1]

Although temperature in the polar climate is not too low to permit the existence of human life, there is no economic basis for existence. Animal life is wholly marine.

[1] Quoted, with omissions, from R E. Peary, *Nearest the Pole*, pp. 123–130. New York: Doubleday, Page, 1907

CITIES WITH A POPULATION OF ONE MILLION OR MORE[1]

London	9,000,000
New York	8,100,000
Tokyo	5,200,000
Berlin	3,800,000
Chicago	3,300,000
Paris	2,900,000
Philadelphia	2,500,000
Vienna	1,900,000
Buenos Aires	1,800,000
Boston	1,800,000
Shanghai	1,500,000
Moscow	1,500,000
Hankow	1,500,000
Calcutta	1,300,000
Osaka	1,300,000
Pittsburg	1,200,000
Peking	1,200,000
Budapest	1,200,000
Bombay	1,200,000
Detroit	1,200,000
Rio de Janeiro	1,200,000
Leningrad	1,000,000
Glasgow	1,000,000
St. Louis	1,000,000
Cleveland	1,000,000
Hamburg	1,000,000
Canton	1,000,000

[1] So far as the data were available these figures are for the geographic or economic city, the so-called "metropolitan district" rather than the political city. For example, in the case of Chicago the figures include not only the political City of Chicago, but also the adjacent municipalities, which, together with the municipality of Chicago, constitute the real city.

Stations	Latitude	Longitude	Altitude of Observatory in Feet	Average Annual Precipitation in Inches	Average Monthly Precipitation in Inches			
					Jan.	Feb.	Mar.	Apr
1. Adelaide, South Australia, Australia	34°56′S.	138°35′E.	141	20.3	0.8	0.6	1.1	1.
2. Archangel, Russia	64°39′N.	40°50′E.	50	15.3	0.8	0.7	0.8	0.
3. Aswan, Egypt	24°2′N.	32°53′E.	363	*	*	*	*	*
4. Athens, Greece	37°58′N.	23°44′E.	351	15.4	2.0	1.5	1.3	0.
5. Austin, Tex., U.S.A.	30°16′N.	97°43′W.	593	33.0	2.0	2.4	2.4	3.
6. Berlin, Germany	52°32′N.	13°25′E.	161	22.9	1.5	1.5	1.9	1.
7. Bourke, New South Wales, Australia	30°3′S.	145°58′E.	460	15.2	2.0	1.9	1.6	1.
8. Buenos Aires, Argentina	34°37′S.	58°22′W.	72	36.6	3.0	2.5	4.7	3.
9. Bukarest, Roumania	44°25′N.	26°6′E.	279	23.0	1.2	1.1	1.7	2.
10. Calcutta, India	22°32′N.	88°20′E.	21	65.6	0.4	1.0	1.3	2.
11. Cape Town, Union of South Africa	33°56′S.	18°25′E.	40	24.8	0.7	0.6	0.9	1.
12. Charleston, S.C., U.S.A.	32°47′N.	79°56′W.	48	48.6	3.1	3.1	3.3	2.
13. Chicago, Ill., U.S.A.	42°18′N.	87°50′W.	600	33.5	2.1	2.3	2.6	2.
14. Cloncurry, Queensland, Australia	20°40′S.	140°35′E.	696	20.0	5.1	4.9	2.7	0.
15. Columbus, Ohio, U.S.A.	39°57′N.	83°2′W.	918	36.7	3.0	3.0	3.5	2.
16. Cue, Western Australia, Australia	27°27′S.	117°52′E.	1,936	7.2	0.8	0.8	0.5	0.
17. Cuyabá, Brazil	15°36′S.	56°7′W.	738	56.1	10.6	8.9	8.1	3.
18. Darjeeling, India	27°3′N.	88°18′E.	7,376	120.4	0.7	0.9	1.7	4.
19. Davos, Switzerland	46°46′N.	9°48′E.	5,121	35.7	1.8	2.2	2.2	2.
20. Delhi, India	28°38′N.	77°12′E.	718	27.6	1.0	0.5	0.7	0.
21. Durban, Natal	29°58′S.	30°57′E.	260	42.2	3.9	4.9	5.1	3.
22. Fort Chipewyan, Alberta, Canada	58°46′N.	111°13′W.	675	13.5	0.9	0.6	0.6	0.
23. Fort Lamy, French West Africa	12°7′N.	15°02′E.	886	21.7	0.0	0.0	0.0	0.
24. Hanoi, French Indo-China	21°2′N.	103°30′E.	52	67.5	0.6	0.8	2.2	3.
25. Harbin, Manchuria	45°43′N.	126°40′E.	525	19.0	0.2	0.2	0.4	0.
26. Hilo, Hawaii	19°44′N.	155°7′W.	40	139.4	9.9	11.5	15.1	13.
27. Iquique, Chile	20°12′S.	70°11′W.	30	*	*	*	*	*
28. Iquitos, Peru	3°45′S.	73°10′W.	328	103.1	10.2	9.8	12.2	6.
29. Kashgar, Sinkiang, China	39°25′N.	76°7′E.	4,035	3.5	0.3	0.0	0.2	0.
30. Khiva, West Turkestan	41°28′N.	61°5′E.	295	2.4	0.2	0.4	0.5	0.
31. La Paz, Bolivia	16°30′S.	68°9′W.	11,909	21.2	3.9	4.5	2.6	1.
32. Lille, France	50°38′N.	3°4′E.	ca. 65	28.5	2.1	1.8	2.2	1.
33. London, England	51°31′N.	0°6′W.	111	25.1	1.8	1.7	1.7	1.
34. Long's Peak (near), Rocky Mountain Park, Colo., U.S.A.	40°20′N.	105°50′W.	8,700	18.8	0.5	0.8	1.9	2.
35. Los Angeles, Cal., U.S.A.	34°3′N.	118°17′W.	293	15.9	3.0	3.0	3.1	1.
36. Mendoza, Argentina	32°53′S.	68°49′W.	2,625	7.2	0.9	1.1	1.0	0.
37. Mexico City, Mexico	19°26′N.	99°8′W.	7,474	23.1	0.2	0.2	0.6	0.
38. Milan, Italy	45°27′N.	9°10′E.	476	39.7	2.4	2.3	2.7	3.
39. Moscow, Russia	54°41′N.	37°40′E.	476	21.1	1.2	1.0	1.1	1.
40. New Orleans, La., U.S.A.	30°0′N.	90°1′W.	51	55.6	4.5	4.3	4.6	4.
41. New York, N.Y., U.S.A.	40°43′N.	74°1′W.	ca. 100	42.5	3.3	3.3	3.5	3.
42. Nouvelle Anvers, Congo	1°36′N.	19°9′E.	1,230	67.1	4.1	3.5	4.1	5.
43. Omaha, Neb., U.S.A.	41°16′N.	95°58′W.	1,103	30.5	0.6	0.8	1.4	3.
44. Palermo, Sicily, Italy	38°6′N.	13°19′E.	231	29.5	4.1	3.1	3.2	2.
45. Pangerango, Java	6°45′S.	106°58′E.	9,918	133.4	18.3	19.7	15.0	12.
46. Pará, Brazil	1°27′S.	48°29′W.	33	93.7	12.7	13.9	13.9	13.
47. Paris, France	48°51′N.	2°20′E.	ca. 170	20.8	1.4	1.1	1.4	1.
48. Pasuruan, Java	7°38′S.	112°55′E.	20	48.9	9.1	10.4	8.0	5.
49. Patagones, Argentina	40°48′S.	62°58′W.	ca. 20	12.2	0.9	0.5	1.2	1.
50. Peking, China	39°57′N.	116°28′E.	131	24.6	0.1	0.2	0.3	0.
51. Point Barrow, Alaska	71°23′N.	156°17′W.	20	5.5	0.1	0.4	0.2	0.
52. Port Darwin, Northern Territory, Australia	12°28′S.	130°51′E.	69	62.4	15.7	13.4	10.2	4.
53. Portland, Me., U.S.A.	43°40′N.	70°15′W.	99	42.6	3.8	3.5	3.9	3.
54. Portland, Ore., U.S.A.	45°30′N.	122°40′W.	57	42.5	6.3	5.0	4.7	2.
55. Port Macquarie, New South Wales, Australia	31°25′S.	152°55′E.	49	61.5	5.9	7.5	6.5	5.
56. Quito, Ecuador	0°14′S.	78°32′W.	9,350	44.1	4.3	4.0	5.3	7.
57. Quixeramobim, Brazil	5°16′S.	39°15′W.	679	23.4	1.7	3.9	6.4	4.
58. Reno, Nev., U.S.A.	39°30′N.	119°50′W.	4,532	8.7	1.7	1.4	1.0	0.
59. Santiago, Chile	33°27′S.	70°42′W.	1,703	14.6	3.0	0.0	0.2	0.
60. Sapporo, Hokkaido, Japan	43°4′N.	141°20′E.	56	38.4	2.8	2.3	2.3	2.
61. Seattle, Wash., U.S.A.	47°40′N.	122°20′W.	160	35.7	4.4	4.0	3.2	2.
62. Semipalatinsk, Siberia	51°0′N.	80°20′E.	590	7.3	0.5	0.2	0.4	0.
63. Singapore, Straits Settlements	1°17′N.	103°51′E.	10	92.8	8.5	6.1	6.5	6.
64. Shanghai, China	31°15′N.	121°29′E.	ca. 15	43.6	2.2	2.3	3.2	3.
65. Spitzbergen (Green Harbor)	78°2′N.	14°14′E.	36	11.8	1.1	1.5	1.1	0.
66. Tomsk, Siberia	56°30′N.	84°25′E.	390	19.9	1.1	0.8	0.8	0.
67. Tosari, Java	7°54′S.	112°55′E.	5,830	67.1	11.2	12.6	8.7	5.
68. Valdivia, Chile	39°49′S.	73°6′W.	49	104.9	2.9	3.1	6.4	9.
69. Valencia Island, Ireland	51°55′N.	10°20′W.	ca. 20	56.0	5.6	4.9	4.1	3.
70. Vera Cruz, Mexico	19°12′N.	96°8′W.	49	67.5	0.4	0.6	0.6	0.
71. Verkhoyansk, Siberia	67°33′N.	133°24′E.	328	5.0	0.2	0.1	0.1	0.
72. Victoria Land (Shore of Ross Sea) Antarctica	77°42′S.	165°35′E.	ca. 50	†	†	†	†	†
73. Wellington, New Zealand	41°16′S.	174°47′E.	141	50.6	3.6	3.3	3.1	4.
74. Winnipeg, Manitoba, Canada	49°53′N.	97°7′W.	761	20.2	0.8	0.8	1.2	1.
75. Wray, Colo., U.S.A.	40°3′N.	102°12′W.	3,512	17.6	0.4	0.7	1.0	2.
76. Yuma, Ariz., U.S.A.	32°40′N.	114°36′W.	141	3.1	0.4	0.5	0.4	0.

* All months practically rainless.

Average Monthly Precipitation in Inches

ine	July	Aug.	Sep.	Oct.	Nov.	Dec.
3.0	2.6	2 3	1.7	1.7	1.0	0.8
1.5	2.2	2.1	2.0	1.5	1.1	0.8
*	*	*	*	*	*	*
0.7	0.3	0.4	0.6	1.7	2.9	2.4
2.5	2 4	2.4	3.7	2.8	2.5	2.3
2.5	2.7	2.2	1.7	2.0	1.9	1.9
1.0	0.9	0.9	1.0	1.1	1.3	1.1
2.7	2.2	2.4	3.0	3.6	2.8	3.9
3.3	2.8	1.9	1 5	1.5	1.9	1.7
1.8	13.0	13.9	10.0	5.4	0.6	0.3
4.4	3.5	3.3	2.2	1.6	1.1	0.8
5.3	6.2	6.7	5.2	3.9	2.7	3.3
3.5	3.6	3.0	3.1	2.4	2.5	2.1
0.3	0.5	0.1	0.5	0.5	1.1	3.0
3.4	3.7	3.2	2.4	2.3	2.9	2.7
1.3	1.0	0.4	0.6	0.1	0.0	0.3
0.4	0.2	0.4	2.7	4.4	6.5	8.4
3.3	31.9	25.4	18.2	5.3	0.2	0.2
4.0	4.9	5.0	3.7	2.7	2 2	2.5
3 4	8.5	6.9	4.5	0.5	0.1	0.4
0.7	0.7	1.2	4.6	5.8	4.2	5.7
1.6	2.6	1.6	1.6	0.8	0.9	0.9
1.8	5.1	7.2	1.7	1.5	0.0	0.0
8.7	13.3	12.2	9.8	6.9	1.9	0.9
3.7	4.4	4.1	1 8	1.3	0.3	0.2
8.1	10.8	12.3	10.8	11.1	14.6	11.7
*	*	*	*	*	*	*
7.4	6.6	4.6	8.7	7.2	8.4	11.5
0.4	0.3	0.7	0.3	0.0	0.0	0.2
0.0	0.0	0.1	0.1	0.1	0.1	0.1
0.1	0.2	1.1	0.8	1.3	1.5	4.3
2.3	2.8	2.5	2.5	3.0	2.8	2.5
2.3	2.6	2.4	2.0	2 7	2.3	2.1
1.5	2.7	2.1	1.8	1.6	0.6	0.6
0.1	0.0	0.0	0.1	0.8	1.3	2.9
0 2	0.2	0.3	0.4	0.8	0.6	0.9
3.9	4.1	4.7	4.1	1.8	0.5	0.2
3.3	2.8	3.2	3.5	4.7	4.3	3.0
2 0	2.8	2.7	2.1	1.5	1.7	1.6
5.4	6.5	5.7	4.5	3.3	3.8	4.5
3.4	4.1	4.4	3.4	3.4	3.6	3.3
5.1	6.3	6.3	6.3	6.6	2.6	9.3
5.2	4.4	3.5	3.0	2.5	1.0	0.9
0.6	0.3	0 6	1.5	4.0	4.0	4.5
3.9	2.2	4.8	5.7	9.6	15.9	18.1
5.9	5.2	4.7	3.7	3.3	2.1	6.0
2.1	2.0	1.9	1.9	2.1	1.9	1.6
2.4	1.1	0.2	0.2	0.5	2.2	6.6
0.9	0.8	0.8	0.8	1.1	0.7	1.7
3.3	8.5	6.5	2.6	0.6	0.3	0.1
0.5	1.3	1.0	0.6	0.8	0.4	0.3
0.2	0.1	0.1	0.5	2.0	4.9	10.2
3.3	3.5	3.6	3.3	3.7	3.7	3.8
1.8	0.8	0.6	1.7	3.1	6.0	7.2
4.6	4.5	3.8	3.9	3.2	4.1	5.9
4.5	0.9	1.5	3.0	3.7	3.7	3.9
4.7	0.9	0.5	0.1	0.0	0.0	0.9
0.3	0.2	0.3	0.3	0.4	0.8	1.1
3.1	3.5	2.5	1.2	0.6	0.2	0.2
2.3	3.4	3.8	5.4	4.2	3.6	3.6
4.6	0.7	0.5	1.9	2.7	5.9	5.9
0.9	1.1	0.4	0.6	0.6	0.6	0.8
6.7	6.8	8.5	7.1	8.2	10.0	10.4
5.7	5.1	5.9	4.7	3.3	1.9	1.2
0.4	0.7	1.0	0.6	1.7	1.3	1.3
2.7	3.0	2.3	1.4	2.4	1.4	1.9
3.0	1.7	2.0	0.4	2.9	5.8	10.0
7.5	15.4	13.5	7.3	5.0	4.4	4.8
3.5	3.7	5.1	4.6	5.5	5.5	6.5
1.9	14.8	8.9	11.6	9.0	3.2	2.0
0.9	1 0	0.9	0.5	0.3	0.3	0.2
†	†	†	†	†	†	†
5.0	5.9	5.0	4.2	3 9	3.6	3.3
3.0	3.3	2.2	2.1	1.4	1.0	0.9
2.9	2.7	2.1	1.1	0.9	0.4	0.3
T	0.2	0.5	0.2	0.2	0.3	0.4

Average Monthly Temperature in Degrees Fahrenheit

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec
74	74	70	64	58	53	52	54	57	62	67	71
7	9	19	30	41	54	60	37	47	35	22	12
61	66	72	81	88	91	91	91	90	84	73	64
47	49	53	60	68	76	81	80	74	67	57	51
49	54	61	68	74	81	84	83	78	68	58	51
31	33	37	46	55	62	65	63	57	48	38	33
84	83	78	69	59	54	51	56	63	70	76	82
74	73	70	62	56	51	50	52	56	61	67	71
26	29	40	52	61	68	73	71	64	54	40	30
65	70	79	85	85	84	83	82	82	80	72	65
69	70	68	63	59	56	55	56	57	61	64	67
49	52	57	64	72	79	81	80	76	67	58	51
24	25	34	46	57	67	72	71	65	53	39	29
87	85	83	78	71	64	61	67	72	83	85	88
29	30	40	51	63	71	75	73	67	55	42	33
88	84	81	74	63	56	55	58	63	68	79	84
80	80	80	79	77	74	75	77	81	81	81	80
40	42	50	56	58	60	62	61	60	55	48	42
19	23	27	36	44	50	54	52	47	38	30	21
59	62	74	84	89	93	87	86	84	79	68	60
77	77	76	72	68	65	65	66	68	70	73	75
−12	−9	5	29	45	54	62	58	45	34	11	2
75	78	86	92	89	86	81	79	82	84	82	79
64	62	68	76	81	84	83	83	81	77	70	66
−2	5	24	42	56	66	72	69	58	40	21	3
70	69	70	71	72	73	74	75	74	74	73	71
71	71	70	66	64	62	61	61	62	64	66	69
79	79	79	78	78	77	77	78	79	80	80	80
22	32	47	63	67	76	82	78	67	54	38	27
23	29	43	58	73	80	83	79	67	52	38	30
52	51	51	49	47	44	45	46	48	50	53	52
36	38	41	48	54	60	63	63	58	50	42	37
39	40	43	47	53	59	63	62	57	49	44	39
23	23	27	34	42	50	54	55	49	39	32	25
53	54	56	58	61	65	67	69	67	62	58	55
74	73	69	62	53	46	47	50	57	62	68	72
54	57	60	64	65	64	62	62	61	59	56	53
32	38	46	55	63	70	75	73	66	56	44	36
12	15	23	38	53	62	66	63	52	40	28	17
54	57	63	69	75	81	82	82	79	70	62	55
30	31	38	49	59	69	75	73	66	55	44	34
79	80	79	78	79	78	76	76	77	77	78	78
21	24	36	51	63	72	77	74	66	54	38	27
51	52	55	59	64	71	76	77	73	67	59	53
50	51	47	51	51	51	49	51	51	50	50	49
75	77	77	77	79	79	79	79	79	79	79	79
37	39	43	51	56	62	66	64	59	51	43	37
80	80	80	81	80	79	78	79	80	82	82	81
74	71	67	60	53	47	47	48	54	59	65	71
24	29	41	57	68	76	79	76	68	55	38	27
−18	−19	−12	−1	21	33	38	38	28	4	−6	−15
82	82	83	82	80	77	75	77	81	84	84	83
22	24	32	43	54	63	68	66	60	49	38	27
39	41	46	52	58	63	67	67	61	54	46	40
73	73	71	66	61	56	55	57	60	64	68	71
55	55	55	55	55	55	55	55	55	54	55	55
83	81	80	80	80	79	79	80	82	83	83	83
32	36	40	47	54	62	70	69	60	51	42	33
67	65	62	55	50	46	46	48	53	56	62	66
21	22	29	41	51	59	66	69	61	49	37	26
39	41	44	49	55	60	64	63	58	51	45	41
1	2	14	38	57	68	72	67	55	38	20	6
78	79	80	77	82	81	81	81	80	80	79	79
37	39	46	57	66	73	81	80	73	63	52	42
−8	−7	−8	4	20	35	41	38	30	19	3	0
−3	1	14	30	45	59	66	60	48	32	11	1
62	61	61	61	61	60	59	59	60	60	60	61
61	61	57	53	50	46	45	46	49	52	56	59
45	44	45	49	52	57	59	59	57	51	48	45
71	73	75	79	81	82	82	82	80	76	74	71
−59	−47	−24	7	35	55	60	50	36	−5	−34	−53
24	17	5	−9	−11	−13	−17	−17	−13	−4	14	25
62	62	61	57	53	50	47	49	51	54	57	61
−4	−1	15	39	52	63	66	63	54	42	22	7
30	30	39	50	59	69	74	73	65	51	39	31
55	59	65	70	77	85	91	90	84	72	63	56

cipitation data.

THE PASTORAL LIFE OF THE MOUNTAIN[1]

"The peculiarity of the pastoral life of the mountain lies in the fact that the movements take place within the same massif, where they are effected between the upper and lower parts of the slopes. In winter men and beasts are gathered in shelters which have a permanent quality because they are the centers of cultivated areas. With the commencement of the good weather the flocks are taken to pasture on the summits round temporary shelters. It is a general phenomenon in the mountains of the Old World. . . . . In Asia the Mantze of Szechwan leave their houses in the summer for pastures at 11,500 feet elevation and more. The inhabitants of Nepal, Bhutan, and Kashmir have their summer chalets, similar without doubt to that Shamlegh which Kipling has described in *Kim*. In Europe, Balkans, Carpathians, Alps, and Pyrenees take to their summit flocks from the valleys for the summer. The crests of the . . . . Vosges and the [higher levels] of the Central Massif [of France] are frequented in the same way. In [Fenno-Scandia], compartively low altitude is balanced by the northerly climate, and chalets at 2,000 or 2,500 feet welcome to the lichens and heaths of the *Udmark*, hill pasture, animals which have been stall-fed in the winter on hay gathered in the cultivated lands of *Indmark*, the home fields.

"If the pastoral life of the mountain is thus balanced between permanent and temporary habitations, it is because the human groups devoted to it practice agriculture in the first instance and stock raising in the second. This combination is the capital fact. It is well illustrated in the French Alps.

"It may be said that stock raising is the vocation of the French Alps. It is conditioned on the existence of vast stretches of natural grazing grounds covering the slopes at altitudes at which the climate becomes too harsh for forest growth. This is the alpine zone of the botanist. These high grasslands, however, are not restricted to the alpine zone. On the lower border they invade the forest. Considerable areas primitively wooded have been converted by man into grassy lawns for which M. Flahault has proposed the term 'pseudo-alpine prairie.' Alpine prairie and pseudo-alpine prairie together constitute what the mountaineers of the French Alps call 'alp' or 'mountain,' what we have also designated here as the pastoral zone.

[1] Philippe Arbos, "The Geography of Pastoral Life," *Geographical Review*, XIII, pp. 567–571, 574 575. New York: American Geographical Society, 1923. The English standard has been substituted throughout for the metric system.

"The great spaces of the pastoral zone, which in at least half of the French Alps covers more than 40 per cent of the surface, can only be economically exploited for summer pasture. But why, one may ask, cannot these high meadows be mown and the hay carried down to the farms? In the first place, the available ground is too scattered and difficult of access; in the second, it is too rough topographically for profitable cultivation. An acre of good mountain meadow produces scarcely 500 to 600 pounds of hay a year. This inferiority of the high meadow is aggravated by the difficulty of transport to the villages. Considerable differences of altitude separate the permanent dwellings from the alp. They are connected by narrow zigzag paths along which the return journey by mule takes 6 to 7 hours. The price of hay gathered under such circumstances is exceedingly high. . . . .

"But, one may ask further, why does not this population establish itself permanently in the alpine zone? Nature is too hostile. The climate is too harsh for cultivation. Even the hardy grains, barley, oats, rye, can hardly stand the rigors—the frosts early and late, the short season for reaching maturity. The area given to crops in the alpine zone has always been limited and is diminishing. Not that the pastoral zone can be described as uninhabitable. There are, in fact, villages or permanent hamlets at higher elevations than many an alp. But existence there is rude. It is often difficult to secure adequate protection against the keen cold of the long winter. In the high valleys of Tarentaise, Maurienne, Briançonnais, Oisans, and Ubaye, where the forests, never very extensive, have been heedlessly destroyed, the inhabitants are reduced to using sun-dried cow dung or excrement of sheep and goats for fuel; sometimes to supplementing the scant source of heat by living in the stable with the animals. This comfortless existence may become a veritable durance under stress of weather. In the month of January, 1915, for instance, no one could set out from or enter Bonneval in Maurienne without risk of death. The tempest tossed a man about like a straw; and avalanches fell all around. Under such circumstances one realizes why the pastoral zone remains without permanent habitation.

"During the bad season the flocks find asylum in the agricultural zone which occupies the lower portions of the mountain valleys. The French Alps have been so actively attacked by the forces of erosion that even the highest and most massive regions inclose relatively low areas. There is not a single high valley where one does not find a stretch, limited though it may be, below 5,000 feet in altitude. Hence everywhere agricultural life can gain a foothold.

"This agricultural zone has long furnished support for man as well as his animals. In fact, up to the later nineteenth century the backward state of communications due to the difficulties of topography compelled the inhabitants of the French Alps to be self-supporting. A proportionally large area was devoted to crops. But, as the mountain was penetrated by roads and railroads, even the most remote villages began to import grain and flour, and concomitantly the area of tilled land diminished. The ground formerly under cereals has been given over to cultivated and natural forage. The area under cultivated grass has been especially extended in the southern Prealps and in the Subalpine valleys of the south. In all these regions, where climate of Mediterranean tendency to drought is inimical to the natural growth of grasses, the soil with the aid of chemical fertilizers today yields in abundance leguminous crops—clover, lucerne, sainfoin. The natural prairies are preponderant in the northern Alps, where the humidity of the air is favorable, and again in the intra-alpine zone, where the cost of transport for chemical fertilizer is heavy. But natural or cultivated meadows today take first place in the agricultural zone of the Alps.

"The strong declivities greatly increase the actual distance between the agricultural and pastoral zones. The journey between them may be not only long and tedious but too hazardous to be undertaken as a daily routine. Certainly it is exceptional for the cattle to have to spend nine hours on the journey to their pastures, yet such is actually the case in Termignon (Maurienne). Even on the average it takes from an hour and a half to three hours. . . . Thus arises periodic migration in place of the daily journey.

"Pastoral life is not always reduced to a simple rhythm between the high pastures and the permanently occupied region; for in the intervening zone, which is often extensive, man and animals can find other resources. To add to the winter forage and to assure the flocks grazing grounds on the way from stable to alp, the mountaineers have cleared the forest for pastures and have planted fields for their own needs. The intermediate stage of exploitation thus constituted is frequently associated with a temporary habitation. Thus the migrations assume complexity. . . . .

"The two extremes between which the pastoral life circulates are the permanent habitation of the agricultural zone, the village, and the temporary habitation of the pastoral zone, the mountain. The mountain is classified according to the animals carried, sheep

or cattle. If the latter, there may be specialization in the way of meat production, if the animals are fattened, or milk production. In the case of all except the milk-producing mountains a few shepherds suffice to care for the stock. Summer migrations of the animals then do not involve human migrations of any extent. It is different if the mountain is devoted to milk production. This requires a numerous personnel.

"Again, distinction may be made between the 'great mountain' (*grande montagne*), and the 'little mountain' (*petite montagne*). In the former, exploitation is concentrated; a great number of animals are placed under the care of a small number of herders; in the second, exploitation is individual and dispersed; each family goes to the alp with its flock. Thus the 'great mountain' displaces only a small part of the population; on the contrary, in the country of the 'little mountains' the valleys are temporarily depopulated. Furthermore, while the 'great mountain' is purely pastoral, the 'little mountain' often supports crops.

"The pastoral zone must not, however, be conceived of as restricted in each section to one and the same type of mountain. It is only in the southern Prealps that one finds sheep exclusively. Elsewhere various modes of exploitation co-exist. In regions of the Provençal mode of life, sheep occupy the upper part of the alp, oxen the lower; in Savoyard regions, sheep, oxen, and milch cows succeed one another from above downward as the grasses become thicker and more luxuriant with descent. . . . .

"The pastoral life of the mountain, however, is in decadence in the French Alps as it is elsewhere in Europe. The causes are various. In this particular case they belong to two general orders of facts—depopulation and economic progress. The depopulation has assumed serious dimensions over large areas in the alpine regions and has greatly reduced the available labor, a result especially serious in the country of the 'little mountains.' On the other hand, stock no longer has to depend on the summer pasturage, increase of natural and cultivated meadows round the villages making it unnecessary to leave them. Pastoral life depends on the solidarity between the lower meadows and the alp, necessary complements the one of the other. Pastoral industry has entered on an intensive phase in respect [to] both sheep and cattle. The former has regard to the fattening of young lambs, which is more easily conducted on the farms than on the mountain; the latter is especially concerned with the utilization of milk either as

butter or cheese. The establishments situated in the villages formerly functioned only in the winter. Now the tendency is to maintain a regular, uninterrupted supply by limiting the summer exodus to the mountain.

"Economic progress with the growth of urban life has worked havoc to the old pastoral life. Holiday resorts and tourist centers have been raised for at least a few months a year to the dignity of small, or even large, towns. Use of hydro-electric power has created seats of industry which have fixed a numerous permanent population. The consequences are twofold. Hotels, shops, and factories retain a part of the workers who formerly went to the mountains in the summer and thus aggravate the pastoral labor shortage. Then tourists, holiday makers, and workers increase the demands on the dairy establishments.

"It is difficult, however, to imagine that the riches of the pastoral zone will be altogether abandoned. In the French Alps as in other mountain countries stock raising remains the chief basis of human existence. In consequence it is likely long to preserve a distinctive characteristic which does not lack an archaic flavor."

ALPINE SCENERY

Alpine scenery is not confined to the Alps. The Caucasus, the Himalayas, the Northern Rockies, the Sierra Nevadas, the Southern Andes, and many other mountain regions possess in greater or less degree the natural features that are so characteristic of the mountains of Switzerland and several adjacent countries. A careful study and comparison of these regions has led to the development of the hypothesis that in all of them numerous valley glaciers or "rivers of ice," heading in extensive snow fields in the upper portions of the mountains in former ages, moved slowly but irresistibly down the valleys, and in places pushed far out onto the plains which border the mountains. These valley glaciers appear to have acted in their upper and middle courses as great rasps or files, scraping, rubbing, scouring, and gouging, and thus transforming the pre-glacial landscape into its now very different form. In their lower valleys and out on the plains, these glaciers deposited the materials they plucked and scraped from the upper reaches of the valleys. With the subsequent disappearance

or marked shrinkage in extent of the glaciers those mountain features which have come to be called "alpine" were exposed to view. Depending upon whether a glacier eroded or deposited material in a particular place, the feature developed is erosional or depositional in character. Glacial erosional features are: gouged or U-shaped valleys, hanging tributary valleys eroded less deeply than the main valley, ice-scoured rock basins, smoothed and polished and striated rock surfaces, blunt and steep-walled valley heads called "cirques," and narrow, serrate divides between valleys. Glacial depositional features are: morainal hills or ridges, mostly in the lower reaches of valleys or where valleys open on to plains adjacent to the mountains, and lakes dammed up by moraines or occupying depressions in moraines. Beyond these morainal deposits there are in many places valley trains or broad outwash plains, deposits of sand and gravel laid down by waters flowing from the melting ends of the glaciers. Altogether, the alpine scenery of glaciated mountains is quite different from the scenery of unglaciated mountains.

THE ORIGIN OF MOUNTAINS

Most mountains have had essentially their present forms from times antedating the oldest records of man. It is believed that the mountain masses came into being hundreds of thousands of years ago through very slow but long-continued uplift. The forces responsible for uplifting these great sections of the earth's surface have been the subject of much interesting speculation by geologists, but as yet are very incompletely known. As uplift was in progress and since it ceased, the various agents of erosion, particularly running water in the forms of streams and of sheet wash, have sculptured the mountain masses into their present forms. Several factors have combined to determine the present forms of mountains, which differ greatly from place to place. The chief of these factors seem to have been (*a*) the amount of uplift; (*b*) the kind and amount of folding and faulting of the rock strata which took place as a consequence of uplift while the latter was in progress; (*c*) the composition of the rocks, particularly their resistance to erosion; (*d*) the presence or absence of volcanic activity; (*e*) the length of time and the intensity of erosion by running water, this last condition largely dependent on the amount of precipitation; and

(*f*) the presence or absence of glaciation, and its intensity, in sculpturing the valleys and peaks, and in depositing materials in the valleys.

From the viewpoint of the geologist mountains are young. Their origin has occupied but a small fraction of the millions of years that the earth has been in evolution, and they will be changed greatly in form within a few hundred thousand years. From the point of view of the geographer, however, mountains, as elements of the natural environment in which men live and work, are essentially unchanging, permanent earth features.

FUNCTIONS OF MOUNTAIN PASSES

Mountains act as barriers which hamper movements of populations, of armies, and of traders. Ranges which are especially lofty, as the Caucasus, or steep-sided and without low passes, as the Pyrenees, detour nearly all movement into routes around their ends. Thus the two main railroads which connect France and Spain flank the Pyrenees, and the railroad from European Russia to the region south of the Caucasus skirts the east end of that range instead of following the more direct and difficult Pass of Dariel. Such skirting routes as these form one type of mountain pass, but because they follow low land they are less picturesque, less difficult to traverse, and less renowned than passes which cross mountain ranges.

The more common type of pass is the breach which provides a crossing of the range easier and at a lower altitude than the crest-line. In most cases this sort of pass is approached from either side by a valley which provides a route of moderate gradient. The usefulness of a pass depends upon its elevation, conditions of snow, the gradient of its approaches, and the size, productivity, and diversity of the regions which it connects. The examples of mountain passes discussed in the following paragraphs portray the functions of typical pass routes.

India is almost completely severed from the interior of Asia by the formidable bastion of the Himalayas, which are tied to the sea at either end by less lofty but intricately jumbled mountains. These barriers

separate regions of sharp contrasts: on the one side, India, with its low latitude climate, its vast plains of arable soil, and its dense, sedentary, agricultural population, and on the other side, the core of Asia, composed of deserts, semi-arid middle latitude grasslands, plateaus, and mountain areas, sparsely populated by nomads. At one point only are the barriers sufficiently breached to permit contact in a significant degree; in the extreme northwest of India the Kabul River and its tributaries lead up from Peshawar, on the plain, to Kabul, in an intermontane basin of Afghanistan, from which routes radiate into Turkestan and Persia. The streams themselves flow in deep gorges, as is usual in mountain country, forcing the road to traverse a series of stream divides, one of which, the Khyber Pass, has given its name to the whole route. Stimulated by contrast in environment, a small trade has found its way over the Khyber from time immemorial, but the fame of the route rests chiefly on the successive surges of warlike nomads, who, forced out of their niggardly homeland by poverty, have swept greedily down upon bounteous and supine India. Conquerors by the Khyber route have imposed more than one government upon India, and the influx of population has submerged the aborigines under stratum after stratum of taller, blonder folk, evident today in the transition from giant Sikhs near the Pass, to short, black Dravidians at the tip of the Peninsula.

The passes which serve as contact points between Mediterranean and Northern Europe are replete with history, for not only are the regions they connect world-centers of production, but in few other places are such contrasted areas in such close juxtaposition. Within historic time these passes have been flooded with whole peoples in migration, they have been fought over from ancient times until the close of the World War, and through the centuries they have borne the loads of a considerable traffic in merchandise. Many are so high, or approached by grades so steep, that they always have been of minor or local significance. Others, such as the St. Bernard, were makers of history in ancient or medieval times, but in modern times have been reduced to local routes because of their unsuitability for railroads. About half a dozen passes are today traversed by the rail lines which carry most of the people and goods, and these alone now possess first-rank strategic importance. These are discussed in some detail below.

The mountains of the Balkan Peninsula may be thought of as a southeastward extension of the Alps barrier between Southern and Central Europe. Through the Balkan Mountains the gently sloping

valleys of the Morava and Vardar rivers map out an easy route between Salonica on the Aegean, and Belgrade on the border of the Hungarian Plain; the crest of this route is only 1,500 feet above sea level. Of some account for trade, this passway has figured more notably in the strategy of the Balkans. The Ostrogoths followed it in their telling assault on the Roman Empire in the fifth century; by way of it the Serbs in their heyday (*ca.* 1350) gained a foothold on the Aegean; the Turks occupied it preparatory to seizing the rich plain of Hungary in the fifteenth century; and in the World War Salonica was the Allies' Balkan base of operations against the Central Powers.

From the head of the Adriatic Sea a much shorter route than the one just described leads into the Middle Danube Basin over the Peartree Pass, less than 3,000 feet high. The deep bight of the Adriatic brings ships very near the head of barge navigation on the Save-Danube river system. For this reason it carried much of the commerce between the advanced Mediterranean lands of ancient and medieval times, and the backward, barbarous plains of Central and Eastern Europe. In recent years railroads have emancipated trade from river transportation, but the commercial value of the route remains unimpaired. This was the route of wave after wave of migrant Germanic tribes who poured into Italy while the Roman Empire was crumbling, and ever since, it has been a bone of contention between Italians and Austrians. In the later Middle Ages Venice controlled the Pass, and with it the trade. Austria at last conquered Venice, but even when forced by the unification of Italy to relinquish the plain at the head of the Adriatic, Austria continued to hold the Pass and its seaboard approaches. A chief objective of Italy in the World War was possession of this territory which her age-long enemy held, and the treaties of peace awarded the area to Italy.

The Brenner Pass, 4,460 feet above the sea, leads across the single divide which separates the Inn, an affluent of the Danube, from the Adige, a river of the Po Plain. The lowest line of communication across the Great Alps, this has been the major highway between Italy and South Germany since the Cimbri invaded the Po Plain, a hundred years before Christ. Afterwards the Romans used it to reach their upper Rhenish and Danubian provinces. Throughout the Middle Ages German emperors hurled through it their armies in repeated attempts to control Italy and the popes. The trade which moved from Venice to Germany was a principal foundation of Venetian wealth, and it made of Augsburg, near the north end of the route, a flourishing

city which in the early modern period was the world's financial capital. When Venice fell to Austria, the fortresses[1] at the Italian end of the route became the invincible outpost of Austrian authority. When Austria was compelled by external pressure to cede Venice to Italy, she retained control of the Brenner Pass, and it was this vital strip of ground, now traversed by a railroad, which Italy received at the end of the World War as part of the district called the Trentino.

Westward from the Brenner, the passes over the Great Alps are higher and more complicated. The St. Gothard alone makes the crossing by a single divide, which is 6,890 feet above the sea. This route, cutting through the heart of Switzerland and connecting Milan with Zürich, is one of several alternate passes between the Middle Po and the Upper Rhine. Although the Romans seem to have been unaware of their existence, these passes carried much of the trade of Genoa, during the Middle Ages, just as the Brenner and the Peartree bore that of Venice. When railroads came to be built, the St. Gothard route was preferred to its rivals, but in order to lessen the grades a tunnel was built beneath the pass.

Since the Alps describe a crescent about the head of the Italian Peninsula, the passes are radial, converging upon the Po Plain. Several routes between the Upper Po Basin and various points along the Rhône were of almost equal importance throughout ancient and medieval times. The renown of the dogs of St. Bernard suggests the importance of that route for travel and traffic; Mont Genévre generally was preferred for the passage of armies. Two rail routes have now gathered to themselves the whole transit business of the Western Alps. The Simplon Pass, bored by the longest tunnel in the world, leads from the Upper Po to the Upper Rhône, whence lines branch to Bern and to Geneva. By way of the Mont Cenis Pass, Turin is linked with Lyons.

Most of the passes of the new world have been in use a comparatively short time. Several, almost unknown until railroads were built through them, now carry very large freight and passenger traffic. Not a few are noted for the grandeur of their scenery or for their extraordinary height. Wars figure very slightly in the history of American passes. Perhaps South Pass in the Wyoming Rockies most nearly parallels the story of its more famous Old World compeers. A gap twenty miles wide at the head of the Sweetwater, a tributary of the Platte River, South Pass is reached by easy grades from both sides. It had been long known to Indians and trappers when the great emigra-

[1] The so-called "Quadrilateral": Peschiera, Verona, Legnago, and Mantua.

tion to the Far West began in 1843. During the decade following, thousands of pioneers made their way to the Oregon country in prairie schooners, on horses, and afoot. This exodus was swelled by the Mormon trek which began in 1847 and by the gold rush to California in 1849. The pony express used the route during its brief but spectacular career, and the regular stage mail and overland freight pursued a longer and more staid existence over the same road. Some twenty-five years after the first considerable group of settlers passed over South Pass, the first transcontinental railroad was laid down along an alternative line about fifty miles to the southward. This fixed the route, much as the Alpine routes have been set in the mold of steel rails.

The foregoing sketch of passways has not taken into account breaches in mountains which are so deeply and widely incised as to constitute complete breaks in the mountain wall. Such lowland routes as these are more closely akin to ordinary lowland plains than to mountain passes. Notable examples are the Rhine-Rhône Trough, the Hudson-Mohawk Depression, and the route of the Southern Pacific Railroad at the southern end of the Rockies.

LAND ROUTES OF TRADE AND TRAVEL

Land routes conform with a good deal of fidelity to surface configuration. This becomes evident in comparing the pattern of transportation routes on plains with that in hill or mountain country. The contrast between the numerous roads and railroads which traverse plains in all directions, and the few lines in mountains, confined to certain well-defined paths, is nowhere better illustrated than in Central Europe.

The Alps form the core of the continent, and together with the Alpine Foreland of South Germany, make up a considerable region of mountain and hill country. Roads and railroads are relatively few, and they follow clearly marked routes nearly everywhere. The number of routes is fewest though the higher ranges of the Alps, where communication between Germanic and Italian Europe is confined to the passes. Through some half-dozen of these passes railroads have been built, but the remainder are served by roads only. In the lower mountains north of the high ranges, roads and railroads compete for

space on the narrow valley floors, and few places are reached by more than one route: viz., that which follows the valley. Between the Lake of Geneva and the Lake of Constance a series of rather wide valleys permits the construction of two or three parallel railroads, connected at a number of places by transverse lines.

North of the Alps the country is characterized by districts of rugged hills, surrounding fairly level basins of some size. In the hills, even though they be low, the chief roads and most of the railroads follow the valleys. It is noteworthy, however, that nearly all the basins are connected by two or more alternative valley-and-pass routes, thus indicating that the restrictions upon communication in hill country are less rigid than in mountains, even though they are similar in character. Within each of the little basins a wheel pattern of routes has grown up, focusing upon some central point. Thus Stuttgart, Munich, Regensburg, Vienna, Prague, Nüremberg, Frankfurt, and numerous other places have come to be local marts of trade. Several places, like Vienna and Frankfurt, lie at junctions of important through routes, and so have become large cities.

On the North European Plain an intricate network of railroads connects the many cities and towns of the region, and the interlaced roads are still more numerous. A glance at the map shows that the railroad lines focus, wheel fashion, chiefly upon two centers, Paris and Berlin, which are joined by several alternative routes across the North European Lowlands. The Paris focus is the outgrowth of conditions on the surrounding plain, which is a saucer-like basin surrounded on the landward sides by a series of ridges that merge into the hill country of Central France, the Vosges, and the Ardennes. Berlin lies in a wide, level depression in the Plain which connects the Elbe and Oder river valleys about halfway between the South German hill country and the sea. Between Paris and Berlin the rough country of upland Europe projects northward to Cologne. The lines connecting the two centers avoid this hill land by passing to the north.

Even more striking than the contrast between plain and mountain routes in Europe is that between the routes of the Mississippi Basin and of the mountain and plateau country to the west of it.

Few places in the humid lowland sections of the Mississippi Basin are more than half a dozen miles from a railroad, and the roads in much of the area are laid out on section or half-section lines, a mile or half a mile apart. Not a few roads and railroads follow streams, and both banks of many larger rivers are traversed by both types of

transportation lines. In addition, routes strike boldly out over the countryside in all directions, so that hosts of small towns, and a few rather large cities, are far from any stream of consequence. Every main railroad line is supplemented by many branch lines. All this is made possible by the gentle declivities in most of the region.

In the western third of the United States the roads are relatively few, and the railroad lines consist of through routes, with branches only where a fertile valley or basin provides a site for settlement. In crossing the Rockies and the Cascades–Sierra Nevadas the most favorable passes have been selected. These are so few that in a number of cases two lines have to use the same valley approaches, although there are less than ten transcontinental lines. The easiest routes focus upon the Great Basin in such a way that the Utah Oasis has become the chief railroad center between the Missouri River and the Pacific Coast. From Great Salt Lake six trunk lines radiate. A similar, but less striking focusing of routes occurs on the Columbia Plateau, where three transcontinental railroads pass through Spokane, Washington. Most of the through roads of Western United States parallel the railroad lines, and there are few local roads which are more than trails. The concentration of routes in an area so vast, where railroads and roads are so few, gives unmistakable evidence of the significance to transportation of land forms in regions where they are in the nature of barriers.

CONTRASTS BETWEEN HILL COUNTRY AND PLAIN, EXEMPLIFIED BY THE EASTERN KENTUCKY "MOUNTAINS" AND THE BLUEGRASS

Two regions not far apart, in which modes of life are strikingly unlike, are the "Mountains" of Eastern Kentucky and the Bluegrass in the center of the same state. Climate is similar in both regions, the "Mountains" not being sufficiently elevated to differ significantly from the lowland; soil differences are not of major significance; ground and surface water is rather more abundant in the hills than on the plain, but domestic supply is obtained largely from springs in both sections; the natural vegetation throughout was deciduous forest. The "Bluegrass" lacks commercial minerals of importance except petroleum, whereas

the eastern hill country contains rich veins of coal as well as oil, but mining has developed only within the past decade or so and has yet fundamentally to modify life in most places. The racial stock and the cultural background of the pioneers of both areas are identical, and settlement occurred about the same time; except in mining communities, no later infusion of immigrants has entered either section. In land forms, however, these regions differ conspicuously, and investigation proves that there is a direct causal relation between land forms and modes of life.

The Bluegrass, at least in its central portion, is a plain of low undulations. There are no vertical lines in the landscape, and few abrupt slopes; all the contours are rounded, and many are still further softened by pastures of bluegrass, delicately green in spring, nodding plumy heads in the summer breeze, or ripe brown-yellow in autumn. The whole countryside is in farms, as attested by the network of fences which enmeshes it. Bluegrass pastures occupy one-quarter to one-half the area of the many stock farms; corn or tobacco fields are conspicuous in the landscape. Even the woodlots heighten the sense of complete utilization of land, for the great, full-formed trees stand, free from underbrush, upon a pastured sward. Spacious houses of the native limestone or of frame dot the landscape. The older ones are likely to be surrounded by stone walls, and nearby a spring may issue from a cave, now walled off for a dairy. As a rule, stock is watered from spring-fed ponds, wells in the regions being unreliable. Many prosperous farms specializing in tobacco contain forty to fifty acres, although dairy or stock farms may be two to four times as large. Roads are numerous, most of them are straight, and they focus upon urban centers as do the spokes of a wheel upon the hub. Nearly all are improved, mostly with macadam made from the native limestone. There are few streams to impede overland communication. Railroads traverse the region readily, connecting one hub with another. Trolley lines link Lexington, the central community, with neighboring county seats. The urban centers are small, few of them numbering more than ten thousand inhabitants. They serve as market towns, county seats, and social centers for the neighborhood, but not as factory towns nor as marts of widespread trade.

The people of the inner Bluegrass live a life in many respects similar to that of rural England. Most of the manual labor is performed by servants (negroes). The landowner plans and oversees the farm work, takes special pride in the breeding of fine horses, and has time left to

devote to the social and political life of the county, state, and nation. Interchange of visits is made easy by the numerous roads, and these, together with frequent trips to the neighborhood center and county seat, keep the inhabitants in touch with one another and with the outside world. The region does not become overpopulated, because there is no immigration, and the native-born who cannot live the customary life of comfortable simplicity migrate to other states.

The "Mountains" of Eastern Kentucky contrast strikingly with the Bluegrass, particularly with its central portion. Stream erosion has incised deep, steep-sided, narrow-floored valleys all over the region, and has left sharp-backed intervalley ridges running in many directions and forming an endless succession of ranges. Gorges and bluffs abound. Steep slopes cut off the view from any point within the valleys. The deciduous forests which crown the hills are dense, and are made more impenetrable by a wild tangle of underbrush. Originally trees clothed the slopes of the mountains as well as their crests, but now much slope land as well as all of the valley floor has been denuded of its forest cover so that it may be devoted to raising corn. Some slopes, too steep to retain their soil once the protecting vegetation is removed, are deeply furrowed with gullies, and have been abandoned to a mat of worthless brush. Much of the land is used only as a feeding ground for half-wild hogs which live on the mast of the forest.

The log cabins of the inhabitants, each close to a spring, are in the deep, narrow valleys which in most of the area form the only lines of communication. In some places these routes consist of wagon roads, in others bridle trails; not a few gravelly stream beds, when dry in summer and autumn, serve for roads, leaving the precious patches of floodplain intact for crops. Floods render nearly all the routes impassable in spring. The county seats are likely to lie at confluences of important streams, for these points are accessible to the maximum number of people. But only six towns in the region of more than thirty counties can muster 2,500 inhabitants. Railroads reach a few coal-mining districts, but they make separate connections with the outside world, and do little to link up the several isolated valleys. So costly is transportation that away from the railroads "store" goods are luxuries, and there are few household conveniences aside from those which can be made at home.

Isolation until recently has been and still largely is the hallmark of the "mountaineers." Unable to get to the outside world, they have developed an indigenous civilization which differs markedly from that

of the less remote neighboring people of the Appalachian Valley to the east, as well as from that of the people of the Bluegrass to the west. Unable to move easily across mountain barriers which separate adjacent valleys, they have lived a life circumscribed by the "settlement," the isolated groups of cabins strung along a single river or fork. Within the settlement intermarriage has gone on until everyone is related to everyone else in a number of degrees. A quarrel with the interbred community of another valley may create a feud which passes from generation to generation. Unable to get about readily even within their own valley, because of floods in spring, press of farm work in summer, or cold in winter, the grown folks cannot attend church regularly, the children are denied the privileges of school, and organized social life is almost unknown. Illiteracy, superstition, and a suspicion of "foreigners," i.e., everybody from outside the county, are natural consequences.

The paradox of hill-land life is that this severe isolation is accompanied by equally unfortunate congestion. The density of population in proportion to the cultivable area is higher than in the Bluegrass. This seems to be a result of isolation and poverty, which precludes emigration even though the pressure of population tends to lower the standard of living. Another form of congestion arises from the custom of the universally large families to dwell in cabins of one or two rooms. Nowhere except in slums of the largest cities is this sort of crowding exceeded. It arises partly from grinding poverty which absorbs the family's energy merely in getting a living, but chiefly from the prohibitive labor required to warm large houses of crude log construction throughout the winter by means of open fireplaces, with their insatiable appetite for wood.

The poverty of the region is suggested by the fact that the inhabitants are exempted from state taxes, and one of the serious problems of a "mountaineer" is to find enough cash for the very low county tax. Money is so rare that barter is the commonest form of trade, but there are few goods to exchange. Most of the native products cannot be sold at a profit after paying the cost of transportation to an outside market. Two exceptions to this rule are ginseng, gleaned in the forests by the women and children, and whiskey made from corn in unlicensed stills in "mountain" fastnesses. Even these are precarious merchandise, for the ginseng is now nearly exterminated, and the moonshiner always has been in conflict with officers of the federal government whose laws he disobeys. Hence the "mountaineers" are compelled

to make the best of their own produce: corn, hogs, tobacco, and perhaps potatoes. One result of this is an appalling uniformity in diet: fried pork, boiled hominy, and cornmeal fried in pork grease, with boiled potatoes now and then. Perhaps because of the character of this diet, ailments of the digestive system are universal, and the lack of properly trained doctors and dentists throws the people back upon herb doctors, home remedies, or fatalistic resignation to a harsh fate. Men and women are old in their twenties, and the span of life is short.

The recent development of coal mining has modified conditions greatly in much of the hill country of Eastern Kentucky. "Where development has been extensive, the land has in many cases passed completely out of agricultural use. In almost all parts of the mountains, the influence of the mines has penetrated; only in the remoter coves at the headwaters of the Kentucky are conditions essentially static.

"Few foreigners entered the mountains prior to railroad construction, and up to 1900 there were relatively few Negroes in the mountains. The small mountain farm did not require slave labor and the hard conditions of life and lack of opportunity for domestic service made the area unattractive to free Negroes. In addition, the mountaineer has never taken kindly to Negroes in the community. At present, however, both foreigners and Negroes have appeard in all areas where extensive mining operations are carried on and in the urban centers which are springing up in response to the needs of the mining communities."[1]

CONTRASTS AMONG THE MAJOR LAND FORMS

Each of the major land-form types possesses its distinctive landscape, which is partly a direct issue of the disposition of slope and flat, and partly a result of differences in use of the land, which in turn to a considerable degree grow out of configuration.

Mountain regions are characterized by high relief, a preponderance

[1] Davis, D. H.: "The Changing Rôle of the Kentucky Mountains and the Passing of the Kentucky Mountaineer," *Jour. of Geog.*, XXIV (1925), 41 ff. Excellent detailed descriptions of the hill country of Eastern Kentucky are to be found in this publication. Probable changes to come with mining development are discussed.

of slope over level land, steep (even precipitous) declivities, and gorge-like valleys. If the differences of relief within a region are as much as three thousand feet, and the proportion, the area in slopes is more than half, the term "mountain country" is appropriate. Mountain features impose severe handicaps upon transportation lines, which are few and costly. Nearly all routes follow the valleys, to which most of the tilled land likewise is confined. Itinerant lumber camps, huts for the seasonal use of grazers or sportsmen, tourist resorts situated to take advantage of the scenic grandeur, and tiny hamlets at the ends of important passways, are the sole habitations on the higher slopes. In short, life in the mountains is concentrated in the valleys, where the population may be dense.

Life on plains, on the other hand, spreads over the whole area. Although few plains are strictly flat, none have much country that is rough, and the relief everywhere is low. As a consequence, people may travel in almost any direction without much regard to land forms. In case the country has been settled slowly, roads converge upon each urban center in a wheel pattern, but in communities that have grown up rapidly, particularly within the past century, it has been customary to adopt a rectangular land survey, with roads laid out like a gridiron. Nearly everywhere on most plains land may be tilled if climate and soil permit, and land not fit for tillage generally may be grazed. The plain is the locale of the large city, for it is only on plains that transportation is sufficiently facile to sustain huge agglomerations of people who produce no food; furthermore, only on plains is there a trade large enough to give rise to large commercial centers, or the possibility of assembling the raw materials for important manufacturing. On a thoroughly settled plain having a favorable climate, the cultural features of the landscape predominate over the natural features. Tilled fields or pastures, marked off by fences, hedges, or walls, caught in a network of ribbon-like roads, shot through with railroad lines, dotted with farmsteads, and splotched here and there with cities—such is the aspect of the settled plain in the middle latitudes.

Plateaus possess attributes of both mountains and plains. The elevation of most plateaus is such that transportation lines which connect with the outside world have steep gradients, and the deep valleys of the plateau itself require costly bridges if they are to be spanned. On the other hand, considerable stretches of level land facilitate internal communication and favor agriculture. Nevertheless, since most plateaus are surrounded by mountain ranges which

cut off precipitation, tillage is likely to be confined to irrigated patches, leaving much of the land to unfenced grazing range. In middle latitudes the population of plateaus is likely to be thinly spread over the whole area, and large cities are the exception. In low latitudes, however, plateaus may be more densely populated than lowlands, because of their superior climate.

Hill country embraces regions which are too rough and of too strong relief to be called plains, but are of too slight relief to be truly mountainous. There is, of course, no sharp distinction between hill country and plains on the one hand, and hill country and mountain regions on the other. These terms are relative, and hold different meanings for different people. The inhabitants of Eastern Kentucky, for example, always refer to their country as mountainous, but persons from the Rockies would hardly call Eastern Kentucky mountainous. Much rough moraine plain in the Middle West of the United States might be called hill country by persons from the strikingly flat plains of the Dakotas, but dwellers in the Himalayas surely would refer to these rough moraine areas as plains. In general, however, if the differences in relief between hilltops and depressions or valley bottoms within short distances are more than three or four or five hundred feet, and if more than half the area is in hill slopes rather than upland or lowland flats, the term "hill country" may appropriately be used.

The population of hill country is likely to be confined either to the crests or to the valleys, depending on which offers the easier transportation routes and the larger amount of tillable land. In either of these situations the population may be rather dense, although large cities are the exception. The proportion of occupied to unoccupied land determines the character of the cultural landscape. Where the maximum percentage of the land is in slope, valley culture predominates. Roads follow the stream-carved routes, houses are strung along the roads, villages lie at confluences or water power sites, and floodplain and stream-terrace make up the principal farmed patches. Typically, the slopes and crests of the hills are forested, but overpopulation may have compelled the inhabitants to convert the lower slopes into farms. Much of Eastern Kentucky is hill country with valley culture.

Where there are considerable strips and patches of fairly level crest land between steep-sided and narrow valleys, upland culture prevails. Roads may be built readily on the interstream expanses, where lie the tilled farms and where the farmhouses dot the landscape. The valleys, useless for agriculture, are permitted to retain their forests.

Each upland district, separated from its neighbors by valleys difficult to cross, tends to develop its own village or city center to care for the commercial and simpler manufactural needs of the neighborhood. Upland culture is illustrated by parts of the Ozarks.

In some hill country slopes are gentle, and the streams meander across wide, ill-drained floodplains. In such regions slope culture predominates. The transportation lines lie part-way up the slopes to avoid floods, the farms are likely to extend from stream to crest, and each farmhouse, facing the road, is thus placed advantageously in the middle of the property. Forest is confined to woodlots, dotted over the landscape at the discretion of the farmer. The district fringing the Catskill Mountains typifies this sort of cultural distribution. Towns lie midway on the slopes, but large cities tend to expand both up and downhill; residences pre-empt the upper slopes and manufacturing and shipping occupy the lands near the river. Many of the Mohawk Valley cities illustrate this tendency.

Combinations of valley, upland, and slope culture occur in nearly every hill region.

FLOODS IN THE LOWER MISSISSIPPI VALLEY[1]

"It is difficult for anyone who has never seen a high-water fight along the lower Mississippi to realize what it means. When the stage of the river at Cairo has reached 51 feet on the gauge, it is a signal for all of those who live along the 1,000 miles of the river below to prepare for a desperate fight against the floods. The approaching enemy, as the crest of the wave may be called, takes about six days to reach Memphis, about twenty-one to reach the mouth of Red River, and about thirty days to reach New Orleans, so that some time is afforded for preparation.

"Millions of sacks are ordered by the levee boards along the river and placed at convenient points so that they may be used in an emergency. Forces are organized, boats are chartered, and guards are stationed so that the levee may be patrolled both night and day. As the flood reaches its highest stage in the river and begins to exert its pressure against the levee, the surface standing from ten to twelve

[1] John A. Fox, *Mississippi River Flood Problem*, pp. 45–55. Memphis: Mississippi River Levee Association, 1915.

feet higher than the land, weak places are discovered and men and materials are rushed to the scene with the utmost dispatch, so that whatever leak may have developed may be checked in its incipiency.

"Sometimes it is possible to prevent a crevasse by thus being on the alert and by working with the utmost dispatch. If a leak has been discovered through which the water is passing in increased quantities, showing that it is gradually cutting a larger hole, a crib is quickly built to exclude the water from the entrance. If it is a case of the water having softened the levee and the embankment sloughing off, additional earth is put on the river side to prevent the water from further seepage. . . . .

"After the levee has broken and the water from the river begins to pour into the country back of it, steps are taken to spread the news as rapidly as possible to all parts that are likely to be inundated. In such sections as are now supplied with telephone lines, the news is quickly conveyed, but in many instances it becomes necessary to put messengers on horseback and dispatch them quickly to isolated points, twenty or thirty miles in the interior, so that the inhabitants may not be taken wholly unaware.

"The water spreads rapidly as it emerges from the opening in the levee, seeking the lower ground and the bayous and parallel streams which will eventually conduct it back into the Mississippi River some hundred miles below, and creeps up steadily day by day into the cabins of the poor and the dwellings of the rich alike.

"A large part of the population scattered throughout these delta lands consists of negro tenants, who rent the land outright or share the crops with the owner. All that they possess is their household goods, their stock and their farm implements. They are prosperous and make a good living with the capital that they have thus accumulated. When crevasses occur, these people lose everything. They attempt to remain in their cabins by building the floor higher as the flood rises day by day, but finally are driven to the housetops and must be taken out by boats sent by relief parties made up in the adjacent cities.

"During the flood of 1912 thousands of these people were rescued after remaining many hours without food upon improvised rafts of logs or in the unsubmerged portion of their houses. . . . .

"People, fleeing from their submerged cabins, seek . . . . elevations to wait in safety above the line of the flood until boats can be sent to bring them out. Most of them escape with scarcely more than the

clothes they have on and the household goods which they can take away with them, their family treasures being bundled up in bedquilts as they flee. Most of these homeless exiles are brought to Memphis, Vicksburg, and Baton Rouge, located on the hills, and are cared for until the water subsides. They can then either go back to their ruined cabins and start over again with nothing but their hands and their will and such credit as may be extended to them by the merchants who will furnish provisions, or seek homes elsewhere in sections of the country not ravaged by the floods.

"During the flood of 1912 the National Government fed 272,753 of these refugees and issued over seven and one-half million rations. . . . .

"The floods that result from broken levees are not fraught with the same danger to human life that accompanies the breaking of the great reservoirs in a mountain gorge. In these cases the flood comes rapidly and whole villages are swept out in an hour and thousands of human lives may be lost. But in the cases along the Mississippi River when the levees break, the great basins are filled slowly, and as the water creeps up gradually into the houses every chance is given to save human life.

"It is not so with the dumb beasts, however, and thousands of head of hogs, horses, mules, and cattle are drowned by the flood waters of the crevasses. Many head of stock that can be quickly herded and taken to the railroads are able to be shipped out and saved, but in many instances in a country that is forty miles wide and two hundred miles long, much of it thickly wooded, it is difficult to gather the stock together in time to save them. They recede to the higher ridges as the waters approach, until finally surrounded, and then they are either drowned in their attempt to swim the intervening gap of twenty or thirty miles, or are starved to death before being reached by relief boats. In 1912, 54,500 head of stock were saved by the Government relief parties. . . . .

"In 1880 there were but little more than 200 miles of railroad line in the entire 29,000 square miles constituting the alluvial delta. So marked has been the development of that country during the last thirty years because of the levee system, however, that 3,800 miles of road now traverse it in every direction. When the levees break and the delta is overflowed, four great transcontinental railroad lines and two of the principal north and south lines of the country are forced to suspend operations. Freight and passenger traffic are interrupted,

the mails are held up, and millions of dollars are lost by damage to the roads.

"The story of the losses by one of these roads, as told by its President, Mr. B. F. Bush, will suffice for all:

"'The Mississippi River overflow in 1912 incapacitated 617 miles of the St. Louis, Iron Mountain & Southern Railway, of which 352 miles was under water, some of it for a period of over five months. The value of the road under water was over $12,000,000 and the physical damage, as revealed by the repairs subsequently made, was $415,000. The loss in traffic has been conservatively estimated at $550,000, which would represent commerce to the value of $5,500,000, which was destroyed. In addition to this, there was a considerable loss occasioned by a great deal of the farming land contiguous to the river not being fit for cultivation the ensuing season.

"'For the year 1913 the physical damage to the Iron Mountain Railway was $460,000, and the loss in traffic is estimated at $196,000. This would make the loss for the two years $9,081,000. To this should be added the two years' loss of farm products by reason of the overflowed land being unfit for cultivation the seasons following the floods. . . . .'

"As the river recedes within its banks and the flow through the break in the levee is discontinued, the back water begins to fall rapidly, and the once inundated region presents a desolate and discouraging view. Bridges have been floated away, drifting logs and tree tops have lodged against the fences and broken them down, and flotsam and jetsam of every character is scattered everywhere. The ground is cracked and in many places covered with white sand, piled up like great snowdrifts, rendering it unfit for cultivation.

"The waters usually recede about the middle of May, and the hot sun pouring down upon the thoroughly soaked earth, the odors arising from decayed material, and the general unsanitary conditions that prevail in such cases make it difficult for those driven from their homes to return and take up their work. They do return, however, with renewed hope and the belief that the flood just passed will be the last one ever to be endured. The ditches are reopened, fences are put back, houses and barns are reconstructed, bridges repaired, and, if seed is obtainable, a crop is planted. After the flood of 1912 many of the people in the Yazoo [basin], as well as in the St. Francis [basin], were able to return and plant their crops in time to derive some revenue from the land, only to have their plantations entirely ruined by the succeeding flood of 1913. . . . .

"There are sixty-nine counties in the seven states affected by these floods, so that by using the loss sustained in one county . . . . as a basis of estimate, some idea may be obtained of the enormous loss that follows when the whole delta is inundated."

A detailed statement of loss through the flood of 1912 in Desha County, Arkansas, follows:

STATEMENT OF LOSS

8,000 bales of cotton destroyed, at $60 per bale	$480,000
4,000 tons of seed, at $20 per ton	80,000
900 head of cattle lost, average price, $8	7,200
160 head of horses and mules destroyed, at $10	1,600
1,500 head of hogs, at average price, $5	7,500
Fences and houses washed away	25,500
Extra expense incurred in fighting the flood	98,000
Expense of closing the breaks in levees	180,000
Loss to business	18,000
Saw-mills, lumber on yards and timber	70,000
Cost to county for repairing bridges and roads	11,000
Plantations practically ruined, caused from break in levee	10,000
Total	$988,800

DELTA CITIES

Nearly every large city in the world is beset with acute problems which arise from its natural environment. Cities on deltas, however, probably have more refractory obstacles to overcome than do those in any other type of location. Among the large delta cities, New Orleans, Rotterdam, Calcutta, and Shanghai may be selected as typical. Originally confined to the natural levee, these cities have grown until they have been compelled to expand over the marshy back country.

Many parts of all these cities lie below the level of the river at high water. For this reason the inhabitants have had to protect themselves from floods by means of artificial levees, built along the crests of the natural levees. In all four cities sections of the levees are occupied by wharves, and in New Orleans and Calcutta by warehouses and railroad tracks as well. In the foreign quarter of Shanghai, a mile's length of the levee is used for a promenade, and in Rotterdam an arti-

ficial embankment about a third of a mile back from the river forms the "High Street," a principal thoroughfare.

The problem of disposing of rainfall and sewage is gigantic. The water-soaked ground can absorb practically no rain, and after each shower the surface slope tends to convert the area back from the river into a lake. Rotterdam has solved this problem in part by a labyrinth of canals, which collect waste water and serve as highways as well. Most of the principal buildings face canals, and the market place is vaulted over a canal. In the native quarters of Calcutta and Shanghai inadequate measures have been taken to carry off either floods or sewage, with the result that cholera and other diseases are rife. Until recent decades New Orleans was little better off. A few sluggish canals ran back from the city to Lake Ponchartrain, which lies lower than the river, and open gutters served for sewers until 1900. Today most of the canals have been filled up[1] and a costly system of covered drains collects surface water and ground water to a depth of several feet. Eight pumping plants distributed about the city, accelerate the flow into Lake Pontchartrain and two bayous. A separate system lifts the sewage into the Mississippi. The foreign quarters of Shanghai and Calcutta have similar systems. In the case of Calcutta the waste is pumped into a depression back of the city, and not into the Hugli River, upon which the city stands. An unexpected effect of drainage in Shanghai was the influx in the foreign quarter of Chinese who could afford it, from the plague-infested Chinese sections of the city. In both Calcutta and New Orleans, garbage and other refuse is dumped into swamps and abandoned canals.

Ground water stands close to the surface on deltas, so that burial underground is uncommon. The old cemeteries of New Orleans are among its most interesting landmarks, with their tiers of vaults, all built above ground. Since the construction of the present drainage system, underground interment has been adopted to some extent in the newer cemeteries.

The problem of providing healthful drinking water is second only to that of waste disposal. Wells are likely to be contaminated; there are no springs, and large deltaic rivers are laden with sediment and disease-bearing bacteria. The usual solution of this problem is to take water out of the river above the city, and to pass it through settling-basins where it is purified by mechanical and chemical means.

[1] Canal Street, the principal business street, is a very wide avenue in which once lay the canal that marked one side of the old French settlement.

In both Calcutta and New Orleans systems of this sort have been put into operation only in the twentieth century. Formerly, at New Orleans, the run-off from buildings was stored in cisterns built above ground, generally open at the top. It was found that these were ideal breeding places for mosquitoes, the carriers of malaria and yellow fever, and they have been abolished by law.

Overland communication with delta cities is difficult to establish and costly to maintain. The bridging of the stream on which the city lies may be impossible. At New Orleans the river varies in width from 1,500 to 3,000 feet, and in depth from 40 to 200 feet. These conditions, added to the insecurity of foundation for piers in the soft alluvium which underlies the area to a depth of many hundred feet, have rendered the construction of a bridge out of the question. Even the railroads are compelled to depend on ferries. At Calcutta three principal railroad terminals lie across the river from the main city, and they are made accessible to foot passengers and vehicles, by a bridge 1,530 feet long, which floats on pontoons. At Rotterdam there are two bridges, one for wagons and one for railroads, but much freight, in addition to that carried by rail, is borne by rivers and canals. There is no bridge at Shanghai across the Whang-poo River, on which the city is located about 12 miles from the Yangtze estuary. The cost of bridging the scores of canals and lesser rivers which crisscross the delta, in order that roads and railroads may enter the city is great.

Closely allied to the problem of securing foundations for bridges and tracks, is that of adequately supporting heavy buildings. As a result, structures in delta cities are only a few stories high. Even New Orleans never boasted a skyscraper until 1920.

Another problem of construction is the absence of building stone on deltas. Such stone as is used must come downstream or from overseas. Because of this, frame buildings tend to predominate in the residential sections of cities, and even the more pretentious edifices are likely to be built of brick, which is easier to transport than stone. Until concrete and asphalt came into use for pavements, the lack of stone seriously interfered with street improvement. Up to 1890 New Orleans had only a few short stretches of pavement, all of which was made of cobblestones brought into the port as ballast.

PIEDMONT PLAIN AGRICULTURE IN SOUTHERN CALIFORNIA[1]

The district covered by the Cucamonga, California, topographic map represents part of an extensive piedmont alluvial plain and the mountains along the base of which it lies. In the center of the plain, bedrock is buried under some 3,000 feet of mantling material, mostly unconsolidated, which has been washed into place by the numerous streams that flow out of the mountains.

To a striking degree the crops of the plain are planted in bands which roughly parallel the mountains. (Figs. 226 and 227). Above the 2,100-foot contour line the land is unused; between 2,100 and 1,050 feet, both sides of the road, except where towns intervene, are planted to oranges, with a few lemons; between 1,050 and 775 feet lies the belt of deciduous fruits—predominantly peaches, but including also orchards of plums, walnuts, and figs; between 775 and 700 feet the land is given over to alfalfa, with some kaffir corn; below 700 feet is the barley zone. This banded arrangement of crops is an outgrowth of environmental conditions.

Of major importance in connection with this zonation of crops is the flow of cold air to lower levels, and the consequent stratification of the atmosphere according to temperature. "Air drainage" is a phenomenon with important economic results both in hill country and on piedmont alluvial plains. As night falls, the cooler air begins to settle to the lower levels, leaving the hill slopes or the upper piedmont in a zone of comparative warmth. Trees planted in this zone are protected from late frost in spring, partly because the temperature remains relatively high, and partly because the movement of air continues throughout the night. (Frosts rarely occur when air is in motion.) Because of the operation of air drainage in the Cucamonga District, the delicate citrus fruits are planted high up on the slope, whereas the somewhat more hardy deciduous fruits and nuts occupy the second zone, and the frosty lower levels are given over to alfalfa and barley, which can endure low temperature. Moreover, the intensive character of orchard farming warrants the removal of stones from the land, whereas alfalfa and barley must be planted on soil of uniform and fairly fine texture. Finally, the amount of water available for irrigation is insufficient to supply the whole plain, and the sections nearer the mountains are in a position to monopolize it. Alfalfa requires

[1] Based largely on data furnished by Charles C. Colby.

much less irrigation than fruit trees. Barley is grown without irrigation. In some sections beans, which require a very little irrigation water, are planted in the zone between the alfalfa and the barley.

Both the land forms and the soils of the Cucamonga Piedmont are very favorable to irrigation, without which farming would be restricted to a few winter crops and to grazing. The steep, high mountains serve as cloud condensers, and the gentle but definite slope of the plain facilitates distribution of the irrigation water. The precipitation runs off the mountain slopes rapidly; it is estimated that about three-fourths of the rain leaves the mountain within forty-five days after it falls. A considerable fraction of the run-off sinks through the permeable soil of the piedmont plain into the underground reservoir of gravel. This fact was not understood by the Spanish pioneers, who located their settlements on the larger washes which provided a flow of water throughout the summer. Even when large-scale irrigation was undertaken in the vicinity of Ontario, a water company was formed to divert the water of San Antonio Creek at the mouth of the canyon and distribute it over the area to be irrigated.

Only after 1899 were the ground water resources of this and other piedmont alluvial plains of California developed. In the ten years 1909–19, the area irrigated from wells tripled, rising from 10% to 21% of the total irrigated land of the state. In the piedmont plain of which the Cucamonga District is a part, 60% of the water now used is derived from wells, and all future expansion must depend upon ground water.

Down to about the 1,000-foot contour line most of the irrigation water is derived directly from the mountain streams. Farther out from the mountains wells are the sole reliance. Their ground water reserves are replenished by flood waters of the streams and by waste water from irrigated fields higher up the slopes. In this way the same water may be used several times in the course of its slow journey across the plain, which probably consumes some seven or eight years. Some of the flood water, which under natural conditions made its way to the ocean, now is spread over the upper margin of the plain, so that it may seep into the soil and ultimately be pumped out for irrigation. The deepest well in the district descends to 1,200 feet, but the average satisfactory well is between 500 and 900 feet deep.

The channels of the larger streams are lined with bowlders and coarse gravel for a distance of several miles from the canyon mouths. The depth of these deposits is sufficient to warrant setting up permanent stone-crushers on the banks of a number of the "washes," as the

stream channels are called, to procure crushed rock for concrete, large quantities of which are used in the district for roads and for irrigation pipe lines. During the dry season the trickles of water which reach the canyon mouths promptly lose themselves in this porous material, but in the rainy season the washes become raging torrents, tumbling bowlders and gravel down their courses, and spreading gravel, sand, and silt widely over the plain. Along Euclid Avenue (the road which runs north and south through Ontario, about midway between two washes), bowlders and coarse gravel are mixed with the sandy soil to a point three miles out from the base of the mountains; coarse and fine gravel are abundant from three to seven miles out from the mountains; sandy silt, with some gravel, predominates in the zone from seven to eleven miles out; and silt of uniform texture surfaces the plain still farther out. Near the washes the coarsest materials extend much farther out upon the plain than they do on the inter-wash areas.

It must not be assumed that the coarser soils are infertile. Indeed, they may be richer in mineral plant food than the silts. In many of the fields on the higher slopes of the plain, near the mountains or alongside the washes, are huge piles of bowlders and stones which have been picked off the land so that lemon or orange orchards might be planted. Nevertheless, the zone lying next to the mountains is uncultivated, a zone which varies in width from a quarter of a mile, as in the vicinity of Euclid Avenue, to five miles or more, as is the case just east of Claremont and just west of Cucamonga.[1] Among the disadvantages of the margin of the plain next to the mountains are steep slope, bowlder-strewn soil, and lack of water for irrigation. The unused land farther down the slope is idle because of stony soil and hazard from floods. In the section below the mouth of San Antonio Canyon ditches are being dug to carry off flood waters, and already pioneers are starting orchards in that district.

In certain sections of the plain, artesian supplies of water have been tapped. An example is the neighborhood of Chino. These artesian flows seem to come from beneath layers of fine, impermeable material which overlies permeable gravel deposits. One such layer is known to underlie the San Antonio Wash and another the Cucamonga Wash. These impermeable layers have an important bearing on ordinary wells, for water generally may be procured in abundance above them, but not for scores or even hundreds of feet below.

[1] Note that all the villages and cities of the plain are situated in the interstream areas.

Land values in the Cucamonga District are high, an acre of orange groves being worth $1,000 or more. The agriculture of the area is intensive and highly specialized. The practices described in the preceding paragraphs are an excellent example of what man may do to make the most of a particular combination of land forms, soil, streams, ground water, and climate.

LAND IN THE UNITED STATES UNFIT FOR CULTIVATION WITHOUT DRAINAGE, 1920[1]

STATE	ACRES	STATE	ACRES
Ala.	2,664,000	Neb.	91,000
Ariz.	23,000	Nev.	53,000
Ark.	4,220,000	N.H.	119,000
Cal.	1,179,000	N.J.	502,000
Colo.	66,000	N.Mex.	26,000
Conn.	111,000	N.Y.	815,000
Del.	188,000	N.C.	5,390,000
Fla.	16,846,000	N.Dak.	137,000
Ga.	6,876,000	Ohio	269,000
Ida.	97,000	Okla.	650,000
Ill.	600,000	Ore.	650,000
Ind.	778,000	Pa.	300,000
Ia.	368,000	R.I.	33,000
Kan.	280,000	S.C.	4,589,000
Ky.	555,000	S.Dak.	209,000
La.	10,431,000	Tenn.	669,000
Me.	1,287,000	Tex.	6,824,000
Md.	499,000	Utah	145,000
Mass.	135,000	Vt.	73,000
Mich.	5,111,000	Va.	1,038,000
Minn.	5,909,000	Wash.	689,000
Miss.	4,752,000	W.Va.	74,000
Mo.	1,085,000	Wis.	4,046,000
Mont.	79,000	Wyo.	13,000
		Total	91,543,000

[1] O. E. Baker, "Land Utilization in the United States," *Geographical Review*, XIII, p. 11. New York: American Geographical Society, 1923.

RECLAMATION OF TIDAL MARSHES[1]

"The embanking of tidal marshes and their use for agricultural purposes date back to antiquity. For upward of three centuries the coastal countries of Europe, particularly those bordering on the North Sea, have been engaged in this practice and have developed in the polders of the Netherlands and the fen lands of England the finest agricultural lands in Europe and drainage works of greater magnitude than elsewhere in the world.

"In this country the reclaiming of tidal marshes extends back about 150 years, but the results obtained have not been wholly satisfactory. The comparatively few permanent successes have been accompanied by so many failures that many people have become discouraged and skeptical as to the practicability of such reclamations. . . . .

"The population of the United States is increasing rapidly, and in one state now exceeds 500 to the square mile. Due to this fact, there is a growing scarcity of good upland farms and a widespread inquiry for detailed information on various phases of marsh-reclamation work. . . . .

"Some [marshes] are old river or lake bottoms filled with the undecomposed vegetable accumulation of ages. These peat marshes, when decomposition is more advanced, become the muck beds so frequently seen along our coasts. The reclamation of such lands should be undertaken with caution. If possessed of sufficient earthy material, they may become extremely fertile, especially adapted to the growing of potatoes, celery, cabbage, and onions, but their shrinkage and consolidation when drained and aerated is very large, and as a foundation for sluices and embankments they are unstable.

"Another type of marsh exists as a barren waste of sand, almost devoid of vegetation. Their reclamation is not likely to be financially successful, as the expense of putting the land in a productive condition is very great, and sand as an embanking material is most treacherous.

"Still another type of marsh is that found behind barrier beaches along outer coasts and in other locations subject to violent wave action. Through long-continued mechanical action of the waves on an exposed coast the bowlders, pebbles, and sand are ground into

[1] George M. Warren, "Tidal Marshes and Their Reclamation," *Bulletin 240, Office of Experiment Stations, United States Department of Agriculture*, pp. 9–10, 16–18, 55–59. Washington: 1911.

exceedingly fine particles, of which the greater portion is carried by the undertow into the sea, but an appreciable quantity remains to be swept by waves and currents into the indentations and inlets of the shore. Moreover, such inlets or estuaries have a tendency to become closed by ridges or barriers of sand heaped up by the sea and the action of winds. The tidal marshes formed in this way are very extensive, but their reclamation is often difficult, because free outfall channels are not easily constructed and maintained.

"Soil is disintegrated rock, and its formation is in progress everywhere through various chemical and mechanical agencies. From the spot of its origin, perhaps hundreds of miles inland, moving water is the vehicle which is ceaselessly conveying it to its resting place to form the fourth and, to the agriculturist, the most important type of marsh. Without the instrumentality of the tides, the fine sand, silt, and clay which is being constantly brought down by rivers would be carried out to sea and lost to man's use forever. The descending fresh water, with its accumulation of detritus, is met and forced back by the comparatively clear water of the flood tide; before the next ebb occurs the silt-laden water has been forced to spread out over the low marshes, and a portion of the suspended matter is deposited. The heavier particles deposit first, thus building up most rapidly the marsh adjacent to the river; the finer, lighter particles are carried farther toward the uplands, and here the marsh-building process is much slower. With the lapse of time enormous areas have in this way been raised, so that they are only submerged by storm tides, and in this condition offer inviting prospects for reclamation and development.

"The rate of tidal deposits varies greatly. A heavily wooded watershed, or one in which the agricultural development has been small, will generally be drained by a comparatively clear river, and the marshes will, in consequence, build up very slowly.

"Most soils shrink when deprived of their water. Experience, both in this country and abroad, has shown that where marshes have been drained there is a long-continued shrinkage or subsidence of the land, the amount of which varies with the depth and character of the soil, being more in those of a peaty or mucky nature, and less in clay, silt, or sand. Approximate subsidences noted in several reclamations are as follows: Green Harbor, Mass., between 1872 and 1908, about 2 feet; Hackensack Meadows, N.J., between 1869 and 1887, from 3 to $3\frac{1}{2}$ feet; Cohansey Creek, Cumberland County, N.J.,

from $2\frac{1}{2}$ to 3 feet; Mays Landing, N.J., about 1 foot; Salem, N.J., $3\frac{1}{2}$ to $4\frac{1}{2}$ feet; Whittlesey, England, 7 feet in 18 years, and in the old reclamations, it is said, the subsidence is still going on at the rate of an inch per year. The drainage of the fen lands has, with the lapse of time, been accomplished only through an ever increased use of pumps. In planning drainage works this tendency to subsidence must be fully appreciated as, if long continued, the ditches become more and more ineffective, and thereafter the water can be removed only by pumping. Failure to discern the shrinkage of marsh soils has caused many to believe that the tides rise higher than in former years, but there is no evidence that such is the case. . . . .

"Marshes composed of a deep soil which contains sufficient clay to render it when moist somewhat slippery under the foot are most likely to prove agriculturally profitable, to be subject to only moderate settlement and subsidence, and to be best adapted to the building and sustaining of levees and sluices, or to the digging of ditches.

"Marsh soils generally show an acid reaction, due to the decomposition of vegetable matter, and require lime as a corrective. The beneficial effects of lime do not continue as long as on upland soils, for it unites with the chlorin, forming chlorid of lime which is soluble in water. Hence applications of lime may on some soils be needed every three or four years. The presence of marl, shells, or other calcareous matter is a favorable sign. . . . .

"Draining marsh land should be done gradually, as otherwise the mechanical condition of the soil may be injuriously affected, its capillary power destroyed, and decomposition of the organic matter retarded. Where fresh water is available and can be promptly removed, much of the saline matter can be washed from the soil. The usual method of subduing a rank sod is by burning, and is to be recommended, despite criticisms which have been made. If the burning does not extend deeper than a foot, comparatively little available plant food is destroyed and the ashes and charred matter improve the texture of the soil, correct acidity, and hasten nitrification. Every facility should be offered for air, rain, sunlight, and frost to enter and act upon the soil. Many marsh soils, in common with clay soils generally, bake when exposed to sun and drought. Plowing should be done in the fall or winter, and when the land is neither very wet nor very dry, [otherwise] a baked or lumpy surface will result, and proper preparation of the land will be rendered difficult, if not impossible. The land should be plowed when gentle rains have brought it

to its most friable condition. The furrow-slice should be shallow the first year and increase in depth in subsequent years.

"Corn is a favorite crop on newly reclaimed marshes, as it withstands considerable acidity. Red top, bent grass, meadow grass, and alsike clover grow well on damp, sour land; and timothy, rye, oats, buckwheat, potatoes, tomatoes, strawberries, celery, melons, and rice have all shown adaptability to marsh soils. Asparagus, onions, beets, and sorghum are crops that resist considerable salt.

"Unreclaimed, the marsh lands have a value of from $1 to $20 per acre, depending upon their location, elevation, and capability of growing salt hay. In general, the values are greater in the more thickly populated North Atlantic States than in the sparsely settled South Atlantic States. Reclaimed, the marsh lands are worth from $20 to $100 or more per acre, varying with the elevation of the land, the character of the soil, and the thoroughness of the development. Probably $50 to $60 per acre would be a fair average value at the present time.

"The acre cost of a projected reclamation will of course vary widely with the extent of the land to be protected, the amount of upland drainage, and the length and height of the levee. Under average conditions it may run from $50 to $60 per acre.

"Marshes which are daily submerged by the tide or are so little above high tide as to be frequently covered through moon, wind, or storm influences are not considered prejudicial to health nor dangerous as mosquito-breeding territory. When the marsh becomes so high or its contour is such that flooding is infrequent the deleterious effects become manifest in malaria, chills, fevers, the mosquito pest, and in certain localities, anthrax. Reclamation of land of this character and its utilization for agricultural purposes has seldom failed to abate the harmful influences and to destroy the mosquito nuisance. . . . .

"In considering a proposed reclamation, the all-important questions to be decided are:

1. What is the character of the soil, especially its fertility and depth?
2. What is the elevation of the land with respect to low tide, and the range of the tide?
3. What is the area and slope of the land?
4. How is the land situated with reference to shelter from storm tides?
5. Is the shore line advancing or receding?
6. What is the amount and character of the upland drainage?
7. Can intersecting streams be diverted?
8. What is the market for the products of the land?

"Especial emphasis should be placed on the importance of carefully considered plans and thorough construction in the matter of levees, sluices, ditches, and pumping plants, as much money has been squandered in the past through hasty, ill-advised, and poorly constructed works."

RECLAMATION OF WET LAND IN THE NETHERLANDS[1]

"Nearly three-fifths of [the land surface of The Netherlands] was formed only during the human period, and made habitable only through man's interference. This is the 'lowlands' of a country that lies almost entirely below the 328-foot contour line.

"The lowlands is a flat alluvial plain separated from the sea by chains of sand dunes locally attaining heights of 200 feet above sea level and broken by wide estuaries and tidal channels. It evidently represents an ancient lagoon closed by a sand barrier and filled by river sediments in co-operation with tidal action. Layers of peat alternating with the silt layers indicate littoral conditions of formation during a time of relative depression of the land (fully 65 feet since the termination of the Glacial Age). The greater part of the surface is below the level of the sea, in places as much as 15 to 20 feet below, and drainage is entirely artificial. Drained and intensively cultivated, these former swamps and lakes are the well-known Dutch 'polderland.'

"The earlier inhabitants, in the days of Caesar's invasion, built low hills, *terpen* or *wierden*, on the marshes exposed to inundation. The hills, which were first raised above the level of high tide, gradually grew in height by the accumulation of the débris of settlement and came to offer comparatively safe refuges for men and cattle in days of storm flood. About 1000 A.D. the first dikes were built, since when they have been constantly improved. The artificial hills [are] no longer needed by the inhabitants, though most of the older settlements (now small towns and villages) in the lowlands of Friesland and Groningen still occupy each a separate *terp*. On the other hand, many *terpen* are now being dug up for use of the black fertile earth as fertilizer. . . . .

[1] P. Tesch, "Physiographic Regions of the Netherlands," *Geographical Review*, XIII, pp. 507-509. New York: American Geographical Society, 1923. The English standard has been substituted throughout for the metric system.

"The first dikes were of a very primitive type and had for their sole purpose exclusion of the inundation waters of rivers and sea. In the fourteenth century the familiar windmill was first used for removing the superfluous inner waters, and the highly distinctive character of the Dutch polderland dates from this time. The mills lift the water via several sorts of ditches and channels to a level from which it can be discharged into the rivers or the sea. For this purpose the whole region of the lowlands is covered by a complex system of drainage, consisting of ditches, dikes, mills, and sluices. In this way it has become possible to control completely the inner water level and to transform lakes and swamps into cultivable land. In the sixteenth and seventeenth centuries many lakes and pools in the provinces of North and South Holland were drained. Since the introduction of large steam pumps, and later electric pumps, the *droogmaking* (making dry) has progressed further and more rapidly; for instance the 'Haarlemmermeer' (lake of Haarlem), measuring 70 square miles, was drained in 1848–1852.

"Up to the present, the greatest and most dangerous of all the Dutch lakes and bays has not yet been brought under man's control. The Zuider Zee, in Roman times a fresh-water basin (*Flevo lacus*), in the middle of the peat land, communicating with the sea by one or more delta branches of the Rhine, greatly increased in size, becoming a real bay (*Almare*) about 1300. The widened and submerged river valleys gave the tidal waves easy access to the interior of the bay. A number of years ago plans were drawn up for control of the area. The inner sea will be dammed by a strong dike running from Wieringen to the coast of Friesland and converted into four polders with a vast fresh-water lake between. In 1918 this important project had received government sanction, and works have already been started by which about 800 square miles of cultivable land will be added to Dutch territory.

"The complicated system of drainage in the polderland has given rise to a number of more or less independent councils and committees, constituted by persons who are directly interested in the watching of the water level and the upkeep of the dikes. The divergent interests of landowners in neighboring polders have always given rise to many difficulties and much litigation. In a country like the Netherlands the question of ruling the waters must always be of extreme practical importance and exigent of continuous survey."

COASTAL DUNES

Along shores of oceans and large lakes where waves and currents are rapidly forming beaches, winds may blow the sand up into irregularly shaped hills called "dunes." This sand is inimical to vegetation because, (*a*) it is extremely poor in plant food; (*b*) it is pervious as a sieve, and hence excessively dry for some eight or ten inches below the surface, and (*c*) where exposed to winds it is constantly in motion. Along the waterfront, where the sand is freshest and most subject to blowing, it permits no vegetation except a few deep-rooted grasses or shrubs. Higher up the slope, the dune itself constitutes a barrier to retard movement of the sand grains; there hardy grasses, able to spread rapidly and to anchor a bit of sand with their tenacious roots, get a hold, and are promptly followed by fast-growing shrubs, and by trees which can throw out roots from their trunks and branches when partially buried by the unruly sand. Should the vegetation prove victorious in this warfare with the wind, the sand is arrested, trees such as pines and oaks grow, and the dune becomes effectively stabilized. In time, a thin layer of humus accumulates, and very old dunes appear to the casual observer much like any other hills. There are differences, however. As the sand drifts inland it leaves depressions of varying depths. Ponds form in some of them, and marshes in others; all have richer, blacker soils than the dunes themselves. The moisture which collects in these depressions stimulates the growth of a dense stand of grassy or bushy vegetation, in contrast to the tree-covered hills. The natural drainage of the country behind the dunes is stagnated by the barrier of hills and ridges, and the land may be converted into lake and marsh very like the smaller depressions within the dunes.

A feature of dunes which greatly curtails their use is the tendency of stabilized dunes to become rejuvenated with removal of the vegetation cover. For this reason, dune land rarely can be plowed with safety, and even felling the trees is risky. A level, fertile field abruptly abutting on a steep bank of bare sand is a startling sight, and to observe the tell-tale yellow streams of sand running down the black furrows of newly plowed ground is to witness nature in one of the quiet but resistless activities whereby the face of the earth is altered.

Perhaps the most interesting dune coast on the world is that along the North Sea, extending with interruptions from Calais to the Zuider Zee. The dunes there are not high—on the average no more than 50 feet, and at the maximum less than 200 feet. The frequent rains and the high humidity keep them fairly stable, although care has to be

taken lest cutting off the trees for fuel or over-close cropping of the vegetation by animals start a "blowout." For at least three centuries people have reinforced the stabilizing activity of the natural vegetation by planting tenacious grasses on exposed slopes. In the nineteenth century trees were set out extensively, but were successful in only a few places.

Since the land on which these dunes lie is low, in some sections below sea level, the value of the dune strip as a natural rampart against the ocean is inestimable. Nevertheless, the plain behind this rampart was a morass because the dune sand choked the mouths of the streams and so obstructed the natural drainage. Today myriads of ditches crisscross the flat, and thus render the land suitable for crops or for pasture. Where the land lies above low tide level, locks at the mouths of streams prevent the entrance of sea water at high tide and permit fresh water to escape at low tide. Where the land lies below low tide level, the water is pumped over dikes into canals or streams the level of which is above the sea.

The inner margin of the dunes is occupied by the main roads of the area and by an almost continuous line of houses, studded at intervals with villages and even cities, including The Hague, capital of the Netherlands, Nieuport, Dunkirk, Gravelines, and Calais. Being higher than the plain, and sandy, this line offers dry locations for buildings and freedom from flood. Moreover, the dunes comprise the only reservoir of good drinking water in the region, and this is tapped near the base of the hills, where the water table lies close to the surface Despite obstacles of hill and sand, roads along the dune base are easier to construct and maintain than any which might be laid out across the plain—muddy, marshy, and checkered with ditches which require bridging. Finally, the best arable land in the region is that which lies immediately behind the dunes, where sifting sand has mingled with and lightened the clay and peat soils of the plain. The world-famous flower fields of Holland lie on this fertile stretch, and truck farms extend its whole length.

On the ocean margin of the dunes live fishermen, and in recent years bathing resorts have grown up along the shore. Scheveningen probably is the most widely known fishing town, and Ostend is a leading seaside resort.

Within the dunes the depressions furnish marsh grass as provender for cattle, whereas their sandy borders are used for legumes, rye, and potatoes, the last named being raised for sale. Because of the cheap-

ness of this type of land, it enables poor people to get a start with little capital; they even may squat upon land which nobody else wants.

The dunes along the Biscayan coast of France are notorious for their instability, and for the fact that their presence is responsible for the Landes (the marshy plain behind the dunes), in all two and a quarter million acres of shifting sand and marsh, occupied by a few poor shepherds compelled to make their way about on stilts. As early as 1717 attempts were made to fix the dunes by planting, but success came only in the nineteenth century, when 275,000 acres were stabilized. Stake and brush obstacles were built on top of the dunes, one above another, as they were buried by sand, until the soil movement was sufficiently retarded for vegetation to gain a footing. Plantings of maritime pine completed the work of reclamation. At the same time the Landes were ditched and planted with this pine, so that an extensive forest has replaced the waste of both dune and marsh. Careful tapping for turpentine and rosin, and cutting selected timber for wood, brings in a tidy revenue each year; the capital value of the whole forest is estimated at ten million dollars.

Cape Cod is one of the better-known dune areas of North America. Sand hills fringe the shores, and a district of ten square miles at the head of the Cape has been built up from shoal water within recent times. Owing largely to the sandy soil and the marshes associated with dunes, Cape Cod has less land under cultivation than any other section of Massachusetts, even the most hilly portions. Among the leading crops are cranberries, which need both marshy conditions and sand, and other bush fruits. Efforts to stabilize the dunes have been more sporadic than in Europe. Indeed, deforestation seems to have been responsible for the creation of serious blowouts. Most of the attempts to arrest dune activity has been centered at Provincetown, where the harbor has been threatened with obliteration. Owing to its position far from the mainland in a stormy and frequented sea, this harbor is so highly valued that the national government has joined state and municipality in fighting the encroaching sand. As in other dune regions, fishing towns and resorts are among the leading settlements.

The dune strip along the southern and eastern shores of Lake Michigan is noteworthy because it is one of the most extensive in the world, and because many of the sand hills rise 200 or more feet above their base. Small ports and summer cottages occupy the shore;

behind the dunes fruits constitute the principal crop of the cultivated lands. The principal roads, railroads, and inland settlements lie well back of the dunes, in the better agricultural lands of the interior. No concerted efforts have been made to stabilize the dunes on Lake Michigan, but brush barriers and plantings about cottages and adjacent to orchards show that the need for protection against the moving sand has been felt even in this new and rather sparsely settled country.

ORIGIN AND CHARACTERISTICS OF COASTAL PLAINS OF UNCONSOLIDATED MARINE SEDIMENTS

Not a few coastal areas have in the recent geologic past been elevated sufficiently to transform shallow sea bottom into land. Such land areas have characteristic features that make them much alike wherever they are found. They border the sea out of which they have been uplifted. They are flat, for the shallow sea bottom out of which they were formed was smooth. Their coastline is low and regular. In many cases tidal marshes extend some miles inland. Long low offshore islands parallel much of the coast, these islands having been built up on bars that developed where the waves broke offshore as they rolled in over the gently shelving sea bottom. The soils on such plains tend to be rather sandy, for only the coarser of the sediments washed into the shallow seas whose floors later were uplifted to form the plains settled near shore. Coastal dunes are common on the sea edges of these plains.

THE UTILIZATION OF ICE-SCOURED PLAINS AND HILL COUNTRY

There are but two extensive ice-scoured regions in the world: Fenno-Scandia (Norway and Sweden, except the southern portions, and Finland) and Laurentia (Canada east of Lake Winnipeg and north of Ottawa). Along the ridge which separates Norway from Sweden, and in one or two places in Central Quebec, the relief is so

strong as to warrant the designation "hill country." Elsewhere both regions are plains of moderate relief.

The outstanding feature of these plains is the large number of lakes in rock basins. In some sections 25% of the surface is covered with water. These lakes range in size from tiny ponds to vast sheets of water, Lake Superior being the largest on either continent. In many cases a number of lakes are connected by streams, or separated from each other by short portages only. This has made water transportation a principal means of communication. In Laurentia the trappers and hunters always have used canoes, designed by the Indians. The light weight of these crafts minimizes the labor of portage. The posts of the great fur-trading companies originally were linked with the outside world and with each other only by canoe routes, and many of them have no other means of transportation even yet. In Sweden and Finland numerous canals, connecting neighboring lakes, provide for continuous boat and barge navigation into the interior.

Outcrops of bare rock are numerous in ice-scoured regions. The ice sheets, in moving out from their centers east and west of Hudson Bay and in Northern Scandinavia, removed most of the surface material, not only loose soil, but all the upper, partially weathered layer of bedrock, thus exposing fresh, unweathered rock surfaces. Much of the bedrock, both in Laurentia and in Fenno-Scandia, is composed of ancient "crystalline" rock which is very hard and resistant to weathering. In the time which has elapsed since the latest ice sheets were melted there has been practically no weathering of the surface of this rock into soil.

It must not be supposed, however, that there is no soil on ice-scoured plains. Stretches of mantling material, left when the ice melted, are interspersed among lakes and outcrops of bare rock, and in depressions sediment and decayed vegetation have been deposited. In most districts, however, the soil is thin and of poor quality, or else marshy. At best, the rural population is sparse and widely scattered. In America, land has been so cheap thus far that little effort has been made to farm any part of the Laurentian Plain. In Fenno-Scandia, a small percentage of the land is cultivated, probably not more than 10%; some wet land has been drained, and thus converted into moderately productive agricultural land.

The latitude of the ice-scoured plains makes their climate as unfavorable to crop production as their soil. Long, cold, and snowy

winters are followed by brief and cool summers. The principal crops are oats (mostly cut green for forage), hay, barley, rye, and potatoes. The people live on rye bread and potatoes, and the hay crops are fed to cattle, which in turn provide milk, butter, cheese, and some meat. Farming, however, produces no surplus for export except butter, and breadstuffs have to be imported. Most farmers have to work part time at other occupations, in order to eke out a livelihood.

The "other occupations" are determined by other natural resources than soil. The natural vegetation is coniferous forest, with some birch and alder. Logging has been the principal industry, at one time or another, of every section accessible to market via water transportation. The forests of Norway, South Sweden, and the Great Lakes Region have been logged off, but the shores of the Lower St. Lawrence tributaries and the streams of Labrador, and most of Sweden and Finland are in the heyday of the lumbering industry, which furnishes full-time occupation for many men, and part time work for many more. Timber may be said to be the economic foundation of life in these areas.

A much more permanent resource than the forests is the water power. The streams of ice-scoured plains are full of rapids, the numerous narrows provide appropriate sites for dams, the channels of hard rock furnish excellent anchorage for dams, and the streams carry almost no sediment. All these conditions combine to make the development of water power easy, and in every section of both Fenno-Scandia and Laurentia all that can be marketed has been developed. In Canada and Finland most of this power is used in the woodworking or wood-pulp industries, but in Norway and Sweden it is utilized, in the form of hydro-electricity, for a variety of purposes besides. The Scandinavians have shown extraordinary originality in applying electric power to novel uses, such as smelting iron, fixing atmospheric nitrogen, running railroads, lighting farms and country roads, and running milking machines and churns in isolated farmsteads. It should be noted that the most of the water-power resources of these areas are as yet undeveloped.

The ancient crystalline rock of which the ice-scoured plains are formed is rich in metals. Thus far prospecting has been confined to the southern margins of both Laurentia and Fenno-Scandia, so that the resources of Canada north of about latitude 50° N., and those of Northeastern Finland, are unknown. Sweden produces the finest

quality of iron ore in the world, and the Lake Superior districts yield the largest quantity. Much of the world's nickel, besides considerable amounts of silver, and some arsenic, copper, and gold, come from the Sudbury District, north of Georgian Bay, and the world's deepest mines have been sunk to obtain the pure copper of the Keweenaw Peninsula, which juts into Lake Superior.

Native animal life ranks high among the resources of the regions. The explorers of Laurentia were hunters in pursuit of fur-bearing animals, and today an important industry is hunting, both for a livelihood and as a sport. The lakes abound in food fishes, which in Europe are consumed locally, and in America are shipped to the populous centers. The most productive ocean fishing grounds in the world adjoin the two ice-scoured plains, and fishermen from Norway, Sweden, and Newfoundland, as well as inhabitants of nearby lands which have not been ice-scoured, have found fishing a lucrative business. The fish frequent shallow waters. Many authorities believe that the sea bottom in these areas was built up in part of material scraped into the sea by the ice sheets. Thus, even the sea-fishing industry is closely linked with the features of ice-scoured plains, which so rigidly prescribe the land occupations of their inhabitants.

All the major resources of these plains can be used only after they have been removed to other regions, and the number of people required to procure them is relatively small. Hence the population of both Fenno-Scandia and Laurentia seems destined to remain scant. Because of the sparse population, the rock-bound lakes, the waterfalls, and the forests, these areas form a paradise for sportsmen and vacationers. Canada has already set aside a national park east of Georgian Bay, and each year larger numbers of people, fatigued by city life, seek recreation in the wilds.

SURFACE FEATURES OF NORTH AMERICA AND EUROPE AS RELATED TO FORMER CONTINENTAL ICE SHEETS

Ice sheets similar to that which now covers most of Greenland are thought once to have covered the northern parts of North America and Europe. The ice is believed to have formed from accumulated snow, and to have moved slowly outward toward the borders of the areas

shown in Figure 240. The ice sheets must have been thick enough to have filled all preglacial valleys and to have covered most hills. In its labored movement, the ice picked up soil and rocks in its lower strata and moved them a lesser or greater distance, dropping them under its surface or leaving them stranded at its melting edge. Both removal and deposition of material took place all over the regions covered by the ice sheets, but there was a tendency for removal to be greatest in the central portions, and for deposition to be greatest in the marginal portions. Most of the material, however, probably was not moved many scores of miles; this is suggested by the fact that nearly all "till" (the name applied to the unsorted masses of clay, sand, gravel, and bowlders deposited by the ice), is composed of material derived from bedrock not many miles distant in the direction from which the ice sheet moved. Thus the till varies in character from region to region largely with the variations in the character of the underlying bedrock. Regions underlain with sandstone tend to be overspread with sandy till, limestone regions with clay till, and regions of resistant, crystalline rocks, such as granite, with thin and stony till. Ice-scoured regions coincide roughly with areas of resistant rock.

Where the ice sheet was active primarily in eroding and removing material, it has left telltale traces in characteristic present-day features, such as smooth and rounded rock surfaces and rock-basin lakes. Where the ice sheet was dominantly at work depositing material, characteristic features are (*a*) a mantle of till covering bed rock to depths varying from a few feet to several hundred feet, (*b*) hills of till and depressions in till distributed irregularly and apparently without system, and (*c*) small lakes or marshes in many of the depressions. Beyond the margins of the ancient ice sheets still other peculiar and characteristic land forms are found today which undoubtedly were developed by the water from the melting ice edge, in the form of streams, sheet wash, or lakes.

There is evidence of several successive ice sheets in both North America and Europe. Where a later sheet more than covered the area of an earlier sheet, little remains in the present-day surface features as a result of the work of the earlier sheet. Where, however, a later sheet was less extensive than an earlier, topographic features developed by each sheet are likely to be present today. In general, the land forms developed by the most recent ice sheets are best preserved.

A significant feature of many moraine areas is a mantle of fine material covering the till to a depth of from one to ten or more feet and free from the stones and bowlders characteristic of the till. This material seems to have been carried by the wind and deposited on the moraines after the disappearance of the ice. It is called "loess."

The present-day lakes and streams of the glaciated areas of North America and Europe have certain characteristics that distinguish them from the lakes and streams of the unglaciated regions. After the disappearance of the ice sheets, the rain that fell in the glaciated regions gathered into the irregularly distributed depressions and, filling them, flowed from higher depressions to lower. The result was the development of stream systems that were quite different from the "normal" stream systems of the unglaciated areas. The stream courses of the glaciated areas are very devious, with unexpected twists and turns. In places the streams widen into lakes or flow through marshes, and in places falls or rapids lead from one section of a stream to another.

DRAINAGE OF WET MORAINE LAND

Hundreds of thousands of acres on the moraine plains of North Central United States and Northern Europe were naturally so poorly drained that they could be cultivated only with difficulty, if at all. Water gathered in the many depressions that characterize the region, some of which are miles wide and appear to be quite flat, others of which are relatively small and clearly defined hollows. Since these hollows and depressions were without natural outlet, due to the uneven manner in which the ice sheets ages before had deposited their burden of till, most of them were wet during much of the year, and some never dried out. Consequently, artificial drainage had to precede tillage. In some places open ditches were dug, and elsewhere drains were put in. In tile drainage shallow ditches are dug through the lowest part of the wet basin and thence through the surrounding higher land to a ravine, stream, or lake. A line of porous tile is then buried in the ditch. As the water seeps through the ground it tends to collect in the lowest part of the depression, where it enters the tile and is carried away. The depth at which the tile is laid varies from $2\frac{1}{2}$ to 4 feet,

depending upon the porosity of the soil, the concentration of rainfall, and the depth to which frost descends.

Flat moraine plains may be tiled even where there are no depressions, in order to hasten drainage.

The additional acreage thus made available for tilled crops is exceptionally fertile, partly because of the deep layer of humus which has accumulated from the decay of rank vegetation. Drainage improves the conditions for growing crops on these lands in a number of ways. It permits free circulation of air within the soil. By withdrawing excess moisture it fosters deep rooting of plants, and so increases both the moisture and food available, and safeguards the crop against drouth.

Wet soils usually are cold, because they require much heat to raise their temperature. When drained, however, such soils warm up quickly in the spring, and permit early plowing and planting. Much of the drained land now tilled could not bear the weight of a plow until its surplus water was removed. A very considerable proportion of the cultivated areas of the moraine plains of the Middle West have been artificially drained, but much still calls for drainage. In North Central Europe many of the moraine plains were drained during the later Middle Ages.

TERRACE TOWNS OF THE UPPER MISSISSIPPI

The Mississippi Valley between St. Paul and Northern Missouri is a broad trench which varies from one to two miles in width, and which is flanked by bluffs averaging 200 feet in height. Seen from the bluffs, the floor of this trench seems to be a single flat plain, but closer examination discloses at least two levels: the floodplain, which occupies most of the area, and separate terraces 10–40 feet above the floodplain, none of which occupies half the width of the valley or extends more than a few miles along the base of the bluffs.

The floodplain is mostly wooded, and is cut into islands or strewn with lakes and narrow streams of back-water. At wide intervals a road or a railroad traverses it on a fill, to connect with bridge or ferry. The only habitations are huts used at certain seasons by fishermen. Where the floodplain occupies the whole width of the valley the rail-

roads and the roads which parallel the stream on either side cling to the base of the bluffs.

It is only on the terraces that activities have a chance to expand. Railroads strike boldly across them; roads traverse them in various directions; farmhouses dot the landscape; and nearly every village and city of the valley has a terrace site.

The terraces make rather poor farm land, because much of the soil is gravelly or sandy, not very rich, and prone to dry out as summer advances. Melons have proved to be a lucrative crop in a few spots where market can be reached easily. Elsewhere rye, which does fairly well on sandy soils and is harvested early, is the mainstay of the farmers.

The terraces are the sites of numerous towns. The primary business of a city is trade, and in the Upper Mississippi region trade always has followed the valley, borne either on the broad stream or by railroads which parallel it. A number of hamlets have grown up as farm centers since the building of railroads. Such villages are likely to be near the middle of the terrace, and may be separated from the river by a mile of floodplain. Each of the older villages and cities, however, is located at a point where the stream washes the base of a terrace. In such a situation wharves and warehouses could be built close to water level without being subject to damage or destruction by floods. Moreover, the terrace offered a flat and sanitary site for the business and residence districts which inevitably spring up at trading foci. St. Paul, Davenport, and others of the larger centers have outgrown their terraces, but the location of the retail business district discloses the terrace site of the original settlement. In these cities the residential districts have been forced on to the upland; in some places the bluffs have been graded to lessen street slopes, elsewhere elevators carry pedestrians and street cars from one level to another.

The terrace towns of the Upper Mississippi are not exceptional. The nucleus of nearly every large valley city in the glaciated section of the United States is on a terrace of glacial outwash. Terraced remnants of ancient floodplains not associated with ice sheets are less common, but have furnished sites for cities the world over. Lack of a satisfactory terrace site has seriously handicapped valley cities otherwise strategically located for trade. An example is Cairo, Illinois, at the point where the Ohio River meets the Upper and the Lower Mississippi rivers. Subject to annual inundations in spite of costly dikes, Cairo was unable to take full advantage of its location; St.

Louis, a terrace city, always has been the principal trans-shipment point for goods and people moving from one of these streams to another.

THE AGENTS AND PROCESSES INVOLVED IN WEATHERING

Bedrock at or near the surface of the earth may be subjected to several agencies and processes that cause it to disintegrate into a mantle of loose material. The chief processes and agents of weathering are: (*a*) oxidation by the oxygen in the air, (*b*) hydration by the water in the air and in the ground; (*c*) solution by the water in the ground; (*d*) cracking due to the expansion and contraction of rock caused by rapid changes in temperature; (*e*) the wedge-work of ice as it freezes in cracks in the rock.

Oxidation and hydration are chemical processes in which oxygen or water combine with certain substances in rock to form new substances. These processes are the same as those involved in "rusting," and in many cases facilitate disintegration of rock. Solution by water removes soluble substances from rock, and this also facilitates disintegration. These and the other processes of weathering enumerated above break up the rock into successively smaller and smaller fragments, and thus eventually transform it into soil.

SOIL CONDITIONS FAVORABLE FOR THE GROWTH OF AGRICULTURAL PLANTS

Soils affect human life chiefly through their ability to produce crops. "A fertile soil [is] one in which conditions are favorable for the growth of plants useful to man."[1]

These conditions are:

1. *Air.* Approximately one-half the space between the particles of soil should be filled with air. The amount of air actually in the soil is determined by

2. *Water*, which, ideally, should fill approximately half the space between the particles. The total amount of water and air in the soil

[1] E. J. Russell, *Fertility of the Soil*, p. 27. Cambridge: University Press, 1913.

should run between 35% and 50% of the volume of the soil, depending upon its fineness. Under identical conditions, clay can contain 53% of water and air, silt 44% and sand 32%. It has been found that the crop yield is highest when there is the proper balance of water and air in the soil. Too much water decreases yields. Moreover, too much water may harm the soil permanently by accumulating hardpan or claypan or by breaking down the clusters of fine soil particles which are characteristic of good tilth.

3. *Temperature*, which is determined by climate and by water content. In low latitudes soil temperature is approximately constant below a depth of two feet. In high latitudes, likewise, the temperature is almost constant at depths below a few feet. In middle-latitudes, on the contrary, it may vary down to depths of 75 feet in the course of the year, and to depths of 2 to 3 feet in the course of a day. Moist soils are more uniform in temperature than dry soils. Because of the large amount of heat required to raise the temperature of water, wet soils generally are cold, and dry soils warm. This condition may be modified, however, by other factors. Sheltered soils, clay soils, and light-colored soils tend to be cold, whereas exposed, sandy, or dark-colored soils tend to be warm.

4. *Root range* is important to soil fertility because the deeper the roots can penetrate the greater the amount of moisture and plant food they can reach. Root range is restricted by excessive moisture and by hardpan or rock. Repeated plowing to the same level tends to develop a compacted layer (plowsole) which acts as a hardpan.

5. *Freedom from injurious constituents* is important to soil fertility. Acids, either in the soil or in the atmosphere, reduce both the yield of plants and the variety which may be grown. Acid (sour) soils develop under conditions of excessive moisture or where the mineral constituents are principally acidic: e.g., silicas. Most metallic salts are injurious to plants. Alkali, if excessive, may preclude vegetation altogether. Alkali soils develop in deserts where the unfavorable salts are not carried away by underground drainage.

6. *Amount and availability of the several plant foods* largely determines the yield of crops. Plants get most of their food, including nearly all their oxygen, carbon, and hydrogen, from the atmosphere and from water. Leguminous plants also take nitrogen from the air. These sources are inexhaustible and fairly constant. The principal plant foods which come from the soil are lime, which is rapidly leached out by water, but which may be rather easily applied in case of deficiency;

magnesia, and iron, always present in sufficient quantity; and nitrates, potash, and phosphates. The last three need to be added to most soils, at any rate after the land has been in crops for a period of years, because they are rapidly removed by leaching and by cropping. Nitrates, potash, and phosphates, therefore, are the principal elements in all soil fertilizers.

That soils differ in native fertility is evidenced by the natural vegetation, either where different species grow in different soils, or where the same species grows differently on different soils. For instance, in middle latitudes conifers ordinarily grow on sandy soils, whereas the finer and richer soils produce deciduous trees. In similar fashion the scrub oak of a sandy soil may be the same species as the towering and impressive forest oak of a finer and richer soil.

Regardless of the original fertility of a soil, once under tillage its ability to yield tends to decline. This is particularly noticeable where the same crop is planted on a given plot of land in consecutive seasons. Decrease in soil productivity results partly from the fact that plant foods are withdrawn by the crops, and partly because poisons excreted by the plants accumulate in the soil. Generally these poisons are harmful only to the species which produces them, so that their evil effect appears only where "single-cropping" is practiced.[1] Devices for maintaining soil fertility have been in use from time immemorial. Perhaps the most primitive is fallowing to permit the accumulation of water or plant foods or both. Fallowing still is practiced among backward peoples throughout the world, and even in parts of India and Russia. In dry-farming regions it is a cardinal principle of scientific farming. As agricultural methods improve, fallowing comes to be looked upon as wasteful of the land, at least in humid regions. In some places, instead of fallowing, crops are planted every year in associations which approximate the natural vegetation. Under these conditions the balance of plant foods in the soil is maintained to a degree, and the association provides an antidote for plant poisons. This device is a feature of the agriculture of China, where legumes and wheat, for instance, are planted in alternate rows, and of Italy, where vegetables and grains are planted among the widely spaced trees of

[1] Single-cropping is practiced only in new countries. It is a modern development made possible by the opening up of vast fertile areas of cheap land, the invention of agricultural machinery, and the establishment of inexpensive and rapid transport between new countries which have foodstuffs to export and old and populous centers of civilization which import foodstuffs.

the orchards. In other highly developed areas, each field is devoted to a single crop, but different crops are successively planted on the same land in a definite series, covering two to six or eight years. This system of rotation varies the drain on plant foods and permits improvement of the tilth by thorough soil preparation. In such a scheme leguminous plants invariably figure, because of their ability to add nitrates to the soil. In some places a part of the rotation system involves plowing under a green crop, such as oats or rye. The advantages of this practice include adding humus to the soil and lightening its texture. Generally, however, "green fertilization" costs a year's crop. The application of fertilizer to the soil is practiced in nearly all parts of the world. Barnyard manure always has been so used, and in India itinerant flocks of sheep are folded on the arable land in order to fertilize it. This practice is held in such high esteem that the landholders pay the sheep-owners. In China and Japan all human excreta are carefully saved and used to enrich the land. Under special conditions it may pay to fertilize fields with concentrates of nitrate, potash, or phosphate. Market-gardens and orchards generally yield high enough returns to afford this luxury, and in some places extensive crops, such as cotton or potatoes, are thus fertilized. A means of adding potash to the soil is widely practiced in grasslands where the natives burn off the vegetation during the drier part of the year. Most such lands, however, are not tilled.

TYPES OF SOILS

No element of the natural environment varies more from place to place than soil. Sharp differences within comparatively short distances are more common in soils than in climate or land forms. Although there are numerous exceptions, in general it is true that of the subdivisions of the land surface of the earth based on elements of the natural environment,[1] soil regions are the smallest, and climatic regions the largest, with land-form regions intermediate in size.

"Soil is a layer of unconsolidated materials at the earth's surface, which has been derived from rocks and organic matter through agencies of decay and disintegration."[2] Since soil is produced from widely

[1] So-called "natural regions."

[2] Hugh Hammond Bennett, *The Soils and Agriculture of the Southern States*, p. 323. New York: Macmillan, 1921.

different mineral constituents, its texture and fertility vary with the character of the parent rock. This is particularly true of soils of recent formation. But since soil is produced in large part by the activities of climate, all soils in a given type of climate tend to become much alike in time.

Perhaps the most striking difference among soils is the contrast between those of dry climates and those of moist climates. Most soils in deserts are light in color. One of the elements which imparts a dark color to soil is decayed organic matter, "humus," which is derived mostly from plant decomposition. Obviously the scanty vegetation of deserts yields little humus. Partly because of lack of humus in the surface soil, and partly because there is relatively little leaching by percolating water, there is almost no difference in the texture and quality of desert soils from the surface down to bedrock.

Many desert soils are sandy. Nevertheless, this sandiness should not be confused with sterility, since nearly all plant foods are present, and desert soils are noted for their ability to endure constant cropping over a long period of years without application of fertilizers. The angular grains of which sand is largely composed, tend to pack and form a hard layer (hardpan) a few inches below the surface. Over extensive areas within the low latitudes this hardpan is a serious drawback to cultivation. In desert soils of middle latitudes the tendency to hardpan is less marked. A surprising characteristic of desert soils is the almost invariable presence of a moist layer 8 to 10 inches below the surface. The coarse, loose texture of the surface material prevents evaporation below a few inches, no matter how hot the surface of the soil may be.

In general, desert soils contain a higher percentage of soluble materials than do soils of humid regions, because the meager rainfall does not dissolve and remove salts from the minerals. Lime and potash are particularly abundant. In some dry regions the common practice of burning off the vegetation each year further increases the potash content. Nitrates and phosphates generally are sufficient in virgin desert soils. In addition to the desirable solubles—lime, potash, nitrates, and phosphates—numerous other salts are concentrated in desert soils. Some of these are harmful: e.g., common salt renders soil impermeable to water, and is in itself detrimental to the growth of most plants. Where excessive quantities of harmful salts are present, the land is said to be "alkali." Irrigation, necessary for the production of crops in such regions, is likely to bring the alkali salts to the surface.

Where this occurs, the harmful substances sometimes are washed out by flooding the fields and allowing the water to percolate through the soil and escape into streams. Depressions are likely to be occupied by alkali lands, numerous patches of which occur in Northwest India, in the Great Basin of North America, in Turkestan and Southeastern European Russia, in the Kalahari and the Karroo, and in Central Australia.

"Adobe" is a characteristic soil of arid regions, including some areas having the dry subtropical type of climate. It is friable, fine-grained, and light-colored. Its texture is resistant to erosion; indeed it stands almost vertical for many years after cutting. Although tough and rather hard to work, it decomposes in the air and therefore does not cake after plowing.

The "regur" soil of the Central Deccan is much like adobe in its texture, fertility, and behavior under the plow. Nevertheless it is black in color, being derived from dark lavas.

The character of soils varies much more widely in moist climates than in dry climates. Moisture aids in the chemical and physical modification of the soil; it favors the growth of vegetation which, on decaying, forms humus, and thus further modifies the soil; and it stimulates the development of bacteria, which are soil factors of much importance to crops. Finally, the moist soils anchored by vegetation are little mixed by the wind, and it is rather common to find sharp lines separating one from another. In all moist soils there is more or less differentiation between the top few inches and the underlying material, i.e., between soil and subsoil. The surface soil contains most of the humus, and is subject in a marked degree to the activities of both air and water. The subsoil is almost or quite devoid of humus; it generally contains a high percentage of water and a low percentage of air. In some cases minerals dissolved from the surface soil are deposited in the subsoil in such a way as to cement it together, forming hardpan. In other cases the finest material (clay) is carried downward a few inches and there concentrated in a layer of claypan.

In addition to the general contrast between desert and moist soils, there is a marked difference between moist soils in the low latitudes and moist soils in middle latitudes.

In the moist low latitudes the constant and high heat stimulates soil formation. Since the native vegetation is rank, there is abundant organic matter, and both rocks and plants decay swiftly. Nevertheless, heavy and frequent rains leach out the plant foods in the soil, and

periods of drouth permit oxidation of humus and minerals in surface soils. As a result, potash, lime, and nitrates are likely to be deficient. Although the soil cannot be called rich, it is enduring, probably because of the rapid replacement of these soluble plant foods. The iron content common to practically all soils is so thoroughly oxidized and hydrated in moist, hot climates that the soil over wide areas has taken on a brick-red color. Soil of this character is called "laterite." Laterite is difficult to work because it packs and is likely to develop hardpan. This necessitates deep plowing. When dry, yawning cracks open in the soil, which becomes as hard as brick. Some soils in the humid subtropical type of climate are red because of advanced oxidation, but they are richer and less difficult to work than the true laterite of the low latitudes.

Volcanic soils occur here and there in the moist low latitudes. Such soils are greatly prized because of their relatively high content of lime and potash. Weathering is so rapid that volcanic cinder may be used at once if it is made up of minerals containing adequate plant food, and even lava may decompose in 5 to 10 years. Generally these fresh volcanic soils lack nitrates and have to be fertilized. Soils of Java, the Hawaiian Islands, and the few notably fertile spots in Central Africa are of volcanic origin.

Soils on limestone likewise are specially favored in the low latitudes, because, unlike most low latitude soils, they are rich in lime. Such soils are found on coral deposits about coasts; e.g., Southern Florida, the West Indies, and the South Sea Islands. Coral soil is light in texture and in color, and is particularly adapted to certain plants such as coco palms and citrus fruits. In many cases it is used for fertilizer on soils deficient in lime.

In moist regions of the middle latitudes the humus does not burn out of the soil so rapidly as in the more continuous heat of the low latitudes; hence humus is a relatively important item in these soils, although the amount varies with the natural vegetation.

Most forest soils in the middle latitudes are less plentifully supplied with humus than soils under grassy vegetation. The leaves from the trees oxidize almost completely as they lie on the ground, and so form little or no humus. Much of the root system of forest plants lies too deep to enrich the surface soil. Moreover the life of these plants is long, and their woody roots decay slowly. Because of the absence of high temperature in middle latitude forests, the iron in the soil is only slightly oxidized. The absence of much humus or of much oxidation

give rise to the gray color which is characteristic of middle latitude forest soils. Since forests are in regions of abundant rain, and since lime is rapidly leached by rain and ground water, most forest soils are poor in lime. They tend to be sour and not especially rich, although they are easily worked, once the trees have been disposed of.

Prairie soils of the middle latitudes contain more humus than forest soils because the unbroken mat of grassy roots yields more organic matter than the leaves and woody roots of trees. For the most part, grasslands are regions of moderate to scanty rainfall, and their soils do not suffer much leaching of lime. Prairie soils are black, therefore, both because of their high humus and high lime content, and are widely known as among the richest soils on earth. (These soils sometimes are called *chernozem*, from the soil of South Russia.) Striking examples of the contrast between forest and prairie soils are found in Central Russia and in Central North America.

Marsh soils are widespread in the middle latitudes. They consist chiefly of humus, which accumulates from the rank growth of vegetation as a deep layer of brown to black soil. Because this soil has been developed mainly under water it lacks air. Therefore it is sour and rarely available for the growing of crops until the top layer of organic material has been aërated and oxidized by burning, or until the application of lime has sweetened it. In some cases both burning and liming are necessary preparations for cropping. Where the land is under water practically all the time, the unweathered mass of dead roots and leaves forms "peat." In marshes which are under water only a part of each year, the vegetation becomes somewhat weathered. Such soil is called "muck." Both muck and peat soils are extremely high in organic plant food, but they are deficient in mineral constituents and after drainage they must be treated to be of much use.

The bulk of most soil is sandy material. Soils in humid middle latitudes, containing 6% or less of clay, generally are classed as sandy soils. Owing to the fact that the high percentage of sand indicates a predominance of quartz grains, which do not contain plant food, sandy soils in moist middle latitudes are usually of poor quality. The flats of Southern New Jersey, the pine lands of Michigan and Wisconsin, the pine barrens of the coastal belt of Southern United States and along the Fall Line of the Carolinas and Georgia, and the heatherlands of Northeastern Germany are examples. The principal rocks from which sandy soils are derived are sandstone, quartzite, mica-shist, and volcanic tuff. The prime difficulty in working sandy soil lies in its

erratic water supply. Because sands lose and gain water rapidly, they form light, warm soils. Fertilizer when added is promptly leached out, and therefore it rarely pays to improve sandy lands. An exception to this rule appears in the case of sandy soils near large cities, where, because of their superior drainage, they warm up early in the spring, and so make excellent market gardens. A market-garden crop is sufficiently profitable to pay for the necessary fertilizer, and since sandy soils are easily worked and rarely develop hardpan, they are highly satisfactory, when enriched, for truck crops.

Clay soils as a rule contain from 20% to 50% of clay. Because of their fine texture and consequent high power of retaining moisture, they tend to be wet and cold, particularly in the spring. At all seasons they are poorly drained and are likely to contain insufficient air. At most seasons they are heavy and sticky and hard to till. If handled wet, clay soils dry as clods, which may become almost as hard as stone. Very commonly unplowed clay soils crack when drying, and the cracks fill by a crumbling process. Then when the rains come, the surface soil is warped up between the cracks, leaving "hog wallows" which interfere with machine cultivation. Clay soils are likely to develop claypan by the accumulation of the finest grains some inches below the surface. This hampers root growth and necessitates deep plowing. Under-drainage by tiling greatly benefits clay soils by improving the tilth, cutting down run-off and consequent wash, and increasing root room. Quite generally under-drainage is worth while, because clay soils are rich in plant food, and they are permanently productive if properly handled. Nevertheless, in very wet climates, such as that of Northwestern Europe, clay soils are pastured except in times of high prices. Clay soils develop on shale and on the crystalline rocks which contain much feldspar, such as granite and gneiss. In some cases clay soils lack lime, which must be artificially supplied.

"Silt" is applied to a texture of soil the particles of which are intermediate in size between sand and clay. Its cultivation generally is easy, and the food it contains is readily available for use by plants.

In most soils the maintenance of a texture suitable for cultivation is dependent upon the presence of lime. Moreover, lime neutralizes acids which make soils sour. For these reasons any soil with a generous lime content generally is thought of as a rich soil. The fact is, however, that basin lime soils are far more fertile than upland lime soils. Basin soils occur on relatively pure limestone. This rock is extremely soluble in water, and it therefore takes a layer many feet thick to

form a few inches of soil; hence the characteristic location of rich lime soils in lowlands. The lime in these basin soils favors the rapid development of humus; in general soils with a high humus content are more productive than those with a low humus content. Moreover, lime acts chemically to prevent souring and to keep the soil particles permeable to water. Famous areas of basin lime soils are the Bluegrass, the Nashville Basin, the Black Belt of Alabama, the Black Waxy Prairies of Texas, the Paris Basin, and nearly all the other well-known agricultural sections of Northwestern Europe. Where the climate is humid, lime tends to accumulate in valley soils of all types, a fact which helps to explain the relative richness of soils in valleys in humid regions.

Not all lime soils are found on lowlands. Where limestone is impure because of the abundance of cherts (resistant rock fragments in the limestone which do not break down readily with weathering), it weathers and erodes less rapidly than where pure, and in places has formed stone-strewn uplands through which the bedrock outcrops in places. Such soil as exists is fairly fertile, although it tends to lack organic matter. On many of the chalk uplands of Northwestern Europe, sheep are folded in order to increase the organic matter in the soil. An extreme case of limestone upland is Dalmatia, which is so stony and rough as to be almost devoid of soil. Some of the better-known examples are the chalk uplands of Northwestern Europe, and, in the United States, the "Knobs" surrounding the Bluegrass, the "Highland Rim" of the Nashville Basin, and the Ozarks. Generally areas having this type of soil are devoted primarily to grazing.

Many volcanic rocks contain a high percentage of lime and therefore are fertile. The presence of lime seems to enable the soil to resist exhaustion in all types of climate. Fertile lava soils cover extensive areas on the Columbia Plateau, the Hawaiian Islands, and the Deccan, and the lower slopes of many volcanoes—including Vesuvius, Etna, and those of the East Indies—are considered distinctly fertile.

Land forms profoundly affect the character of soils. On marked slopes, wash and creep combine to keep the soil thin, and percolating water tends to leach out plant food and the lime which is so necessary in maintaining satisfactory tilth. Gentle slopes and flats, on the other hand, tend to develop deep soils, rich in lime.

On some plains and plateaus the bulk of the soil lies essentially in the position in which it was formed. Such soils, called "residual," owe their character to the underlying rock, the climate, and the vegeta-

tion. Their suitability for cultivation varies with texture and with content of plant food and lime. If the processes of weathering have been at work for a long time, and the agents of removal have been relatively inactive, residual soils are likely to be deep. In some parts of the Piedmont of Southeastern United States residual soils are said to be scores of feet deep. On most types of land forms the soils are wholly or in part "transported" (i.e., removed from the places of their origin), by water, wind, or ice, and laid down as alluvium, lacustrine or marine deposits, dune sand, loess, or till.

Soils which have been brought to their present location by running water are called "alluvial" and, like all transported soils, are not related in composition to the underlying rock. Alluvium varies from coarse gravel to the finest clay, although the bulk of it is silt. Generally it contains a goodly amount of humus, even in arid regions, and rather more lime than is usually found in residual soils. Because of their considerable content of lime and humus, and because of their even texture, alluvial soils are easy to plow, even when wet, and are highly productive, rarely needing fertilizer. In humid regions they are black or dark brown. The most recent alluvial soils are found on river deltas and floodplains. Such soils, because of their location near the level of the stream, are likely to be wet and cold. In areas of older alluvium, whether terraces or extensive plains, the soil is less rich than on floodplains but better drained and warmer; because its humus has become partly oxidized, it is lighter in color. Examples of extensive deposits of "old alluvium" are the Ganges and the Hungarian plains.

Materials laid down by waves and currents in seas and lakes generally grade from gravel or sand along shore to the finest clay some distance out. If subsequently the water is drained off, the resulting soils vary in fertility in accordance with texture, the coarsest in general being least fertile.

Some soils are the result of work by wind, which picks up materials in areas where the ground is without a retentive cover of vegetation, as is the case in arid regions, and on beaches and stream flats everywhere. The heavier particles carried by the wind are deposited near the source of the material as dune sand, which is coarse, light both in texture and color, extremely pervious to water, poor in plant food, and consequently almost wholly unproductive.

Much more widespread than dune sand is the silt and fine sand picked up by the wind and blown considerable distances, in some cases hundreds of miles. This material is fine and uniform in texture,

is moderately pervious, and does not form clods when wet. In spite of its light texture, however, it stands in cuts in nearly vertical cliffs, an indication of its perviousness and resistence to erosion by running water. As a rule it contains a high percentage of plant food in a form easily available to crops. Its only drawback is a tendency to develop hardpan under humid conditions. This wind-blown material, called "loess," is widespread (*a*) on the margins of deserts, (*b*) over a large part of the moraine plains of the world, and (*c*) in the vicinity of some active streams. The loess deposit of Northwestern China mantles hilltops, slopes, and valley floors to a depth varying from a few to scores of feet over an area of more than 200,000 square miles. There are considerable deposits on the Great Plains of the United States and in the Columbia Basin. All these are associated with deserts. Much of the till of North America is covered more or less completely with a thin coating of loess. It is this fact which accounts in large measure for the extraordinary fertility of the Corn Belt of the United States and the Spring Wheat Belt of the United States and Canada. Along the eastern border of the Lower Mississippi Valley there is a deep deposit of loess some miles wide. These moraine and valley loess deposits seem to have been made at a time when much of the areas involved were devoid of vegetation because of cold, and when numerous active streams led from the fronts of the ice sheets which once covered Northern and Central North America.

Soils composed of materials transported and laid down by glaciers occur in glaciated mountain valleys and in the two large regions covered by ice sheets during the later periods of glaciation. Glacial till is so diverse in texture, in mineral composition, and in thickness, that almost no generalization can be made with regard to till soils. The bulk of the till, however, was derived from bedrock not far distant. For example, the sandy tills of East Prussia and of Central Wisconsin and Michigan are directly associated with sandstone, and the limey tills of the Corn Belt and of considerable sections of Western Europe are directly related to underlying limestone formations. Most till is composed of particles of varying sizes, which may range from the finest clay to huge bowlders, all mixed together without sorting. Some till is so stony as to be unsuited for cultivation. Parts of New England owe their abandoned farms to bowlder-strewn till, which cannot be worked profitably in competition with the finer till of the Middle West. Where covered with loess, the till is of importance to crop production chiefly as subsoil.

The types of soils mentioned in the preceding paragraphs are only a few of the more widespread examples. It must be borne in mind that all conceivable variations and combinations of these soils exist, and that clean-cut divisions between soil types are uncommon. This situation has given rise to an elaborate system of names used by experts for classification, such as fine sandy silt, reddish-brown clay loam, and so on.

THE DESTRUCTIVENESS OF EARTHQUAKES

Earthquakes have commanded attention from the earliest times, because of the startling suddenness with which they destroy lives and property. The districts subject to recurrent violent shocks are numerous and large and many of them are densely peopled and contain numerous cities. California, Chile, Japan, Assam, Italy, and the West Indies lie wholly or in part within earthquake zones, along with much larger areas of scanty population. Moreover, destructive earthquakes may occur in regions far from the usual seats of disturbance, as at Lisbon, Portugal, and Charleston, South Carolina. Probably no place can be guaranteed exemption from severe shocks.

Shearing in the rocks of the earth's crust and the consequent vibrations, which are called earthquakes, occur most frequently where high lands dip steeply into deep oceans. It is not the magnitude of the slip, presumably, but its suddenness, that causes the earth tremor.

The damage done directly to the earth's surface even by a severe shock is relatively slight, consisting of cracks, heaved sod, landslides on steep slopes, and permanent or temporary modification in the flow of springs. Trees sometimes are uprooted or snapped off, and people and animals may be thrown to the ground. It is works of man which suffer most, however, and the more elaborate they are the greater the destruction. The grass hut of a jungle-dweller may be shaken, but only the most severe vibration can throw it down, and its fall is unlikely to injure anyone, while repair consumes but a few hours. But even a moderate tremor wreaks appalling devastation upon a modern city, as illustrated by the experience of San Francisco in 1906.

Within the city, chimneys and water tanks fell quite generally, most buildings of masonry were more or less ruptured, frame structures were wrenched and in many cases displaced from their foundations,

and poorly constructed edifices were practically demolished. Buildings erected on ground reclaimed from tidal flats suffered most of all, because of the instability of this type of land. Street pavements were heaved and cracked, and railway tracks were buckled or broken. A number of people were injured by being knocked down or thrown from their beds, or by being struck with falling timbers, slates, bricks, or stones. Electric wires fell, and gas pipes cracked and broke. Fires, live wires, and escaping gas set simultaneous conflagrations throughout the city. These completed the work of death and destruction, and could not be extinguished for days because the water supply had been cut off by breaks in the mains. In the frantic confusion families were separated, and thousands found themselves without shelter, food, or water. Valuables left unprotected were stolen by lawless folk who infest every large city, and martial law had to be proclaimed. Aid presently poured in from outside, and the citizens set themselves resolutely to the task of rebuilding the city, but at this writing, eighteen years after the catastrophe, heaps of broken bricks and remnants of foundations here and there throughout the heart of the city attest the destruction wrought.

The shock which caused this devastation lasted only one minute, but its effects extended from Humboldt Bay to King City, in a line 350 miles long, along which the surface of the earth was horizontally displaced not less than 10 feet in most places, 15 feet in many, and 21 feet at the maximum. Fences and roads were offset, and latitude, longitude, administrative boundary lines, and property surveys were altered so much that new triangulations and surveys had to be made. The width of the zone affected approximated 70 miles. Even where there was no destruction, loose objects were displaced, furniture slid about, pendulum clocks stopped, pendant fixtures swung in more or less elliptical orbits, windows and dishes rattled, trees swayed, and animals and people were terrorized.

When earthquakes are centered under the sea they may cause enormous waves which wash away towns and their inhabitants. Just as the fire was more destructive than the earthquake in San Francisco, so in Sicily in 1908, a series of waves, reaching 38 feet in height, far exceeded the damage caused by the earth shock. On the coast of Chile in 1922, waves swept boats a mile inland, and their repercussion was felt at Hilo, Hawaii. In the Japanese earthquake of 1923 tidal waves on the shores of Sagami Bay rose at least 50 feet in places and lasted ten or fifteen minutes.

This last was the most devastating earthquake recorded. The principal damage affected an area with a radius of about 30 miles about the town of Yokosuka (at the entrance of Tokyo Bay), containing five large cities, including Tokyo, the capital of the country, and Yokohama, one of the two leading ports. The total population of the district comprised about 7,000,000 inhabitants.

This area was subjected to "intense vertical shaking that resembled an up-and-down pounding from below, [and in at least two localities] this sort of violent motion was repeated again and again during twenty-four hours."[1] Marked changes in the shorelines and depth of sea-bottom resulted. In most places the land was lifted from one to eight feet above sea-level, but in one district it sank two or three feet beneath the sea. The combined elevation and subsidence of the floor of the bays of Tokyo and Sagami amounted to from 50 to 200 fathoms in different places. In hilly country, the surface material of slopes steeper than 30° slid, carrying forests and villages to destruction. All over the area, especially on alluvial and made land, there was much cracking of the surface. Along the point which forms the eastern side of the Bay of Sagami a fissure 20 feet wide and 8 feet deep developed between the beach and the sand dunes.

The good-sized city of Yokohama was practically wiped out, owing in a measure to the fact that it was built largely on made land. The shaking is reported to have consolidated the loose surface materials, so that the town site has been lowered four feet. The following description was written to an American benefactor by a native guide who chanced to be in Yokohama at the time.

"Earth Quake occurred at 11.50 in my watch. I thought usual small ones, which I often experience in Yokohama and Tokio. No, no, very big terrible, fearful; bricks begun fell down from upper sides over my head, big sounds, house crack and inclined nearly to fell down. At this very moment the earth quake stopped. [We] cried out for help through the window, found no houses at all, all smashed down already; and [we] went toward staircase like rat and went down. Door at entrance [had to be] broken into two and opened, then we three rush out, found all houses on the street smashed down. Again big quake occurred, but this time was quite safe, as none to smash except [the house we had just left], 12.20. Fire, smoke round there at 12.25. Many wounded neighbors came and ask for help. We went to the [waterfront] after hard difficulty, as road obstacled with brick and

[1] T. A. Jaggar, in a letter to the authors.

smashed houses (water front is newly filled-in ground). 12.40 Grand Hotel in fire, British and American hospitals on the bluff in fire at 12.50. French consulate in fire at 1.00 P.M. Several big quakes during these time, very dangerous as ground split all over."

Next to Yokohama, Tokyo suffered most damage, at least half the city being destroyed, including the business district and most of the public and semi-public buildings. The shock damage there was confined chiefly to bottom lands and the margins of canals; as at San Francisco, fire was the real destroyer. The first shock occurred just before noon, when there were fires in all the kitchens. 120 different conflagrations started simultaneously in various parts of the city, and a high southwest wind made it impossible to quench the flames. In the evening the wind suddenly shifted to northerly, thus causing the fire to surround crowds which had taken refuge on the windward side of the first fires. This change of wind direction greatly increased the appalling loss of life.

Estimates of the total damage to the whole area vary considerably. Approximately 1% of the annual food supply of the nation was destroyed, along with one month's export of raw silk, the chief export of the country. Yokohama being a leading Japanese port, commercial interests lost heavily. Since Tokyo was a principal manufacturing city, factory interests likewise suffered, particularly the cotton-spinning industry. Between 10% and 15% of all the spindles in the country were destroyed. The total property loss has been put at slightly less than one billion dollars, which amounts to about 2% of the national wealth. This does not take into account the priceless objects of Japanese art which were lost. The loss of life totaled scores of thousands; estimates of dead and missing range from 150,000 to 450,000.

THE DESTRUCTIVENESS OF VOLCANOES

The striking phenomena of volcanic activity and the terrific destruction wrought by violent eruptions have attracted much attention from both scientist and layman. Nevertheless, the geographic significance of volcanoes is negligible, save in a few localities. The area subject to visitation by eruptions is small, and except for Japan, Italy, and a few places in Middle America, volcanic districts are sparsely populated.

By all odds the most famous active volcano in the world is Vesuvius. Its reputation is due mainly to the fact that it stands in a densely peopled district which has had a long history. From earliest times the flanks of Vesuvius have been cultivated from the base up to heights where the slope is 10° or 12°; the base of the mountain thus has a girdle of cultivation two miles or more wide with a total area of at least 40 square miles. The deep, fertile, lava soil produces excellent wine grapes, the intensive culture of which has given rise to an exceptionally dense rural population that lives in villages strung along a road which encircles the mountain's foot. The surrounding plain likewise is dotted with farms and villages, and along the Bay of Naples, close to which the volcano rises, are cities and towns, including populous Naples. The upper limit of cultivation and habitation is fixed by the extent of recent and hence unweathered lava flows. This lava zone, extending from the 1,500 to the 2,500-foot level, a mile wide at the point of greatest extent, is devoid of vegetation. It has been compared to "a stormy sea of boiling pitch [which] has been suddenly cooled, so as to retain in a solid form all the roughness . . . . and irregularity which the surface possessed while liquid. In some places [it simulates] great coils of thick, black ropes, but in others, sharp and rugged ridges, like the crests of breakers, ... and in others, again, huge blisters . . . . , while large areas are covered . . . . with smoother rolling waves."[1]

Above this lava stands the cone, covered with both lava and loose ejectamenta, which reaches an altitude of about 4,000 feet. A semicircular old and larger crater, half blown off in the theatric eruption of 79 A.D., stands like a ruff behind the cone, and protects the inhabitants on the landward side from lava flows. The seaward side, lacking this protection, has been devastated from time to time, when violent eruptions have spilled enough lava to reach the cultivated slopes. For a time after an eruption these streams resemble the unweathered lava of the upper levels, but in the course of a few decades enough soil forms to permit cultivation again, and the scar is healed. Thus the seven wide floods of the eruption of 1631, several of which reached the sea, have been farmed since the early eighteenth century.

Despite the repeated desolation caused by lava flows, the inhabitants of the district display an amazing nonchalance in the face of ordi-

[1] J. Logan Lobley, *Mount Vesuvius*, p. 124. London: Roper and Drowley. 1889.

nary eruptions. Men work fields separated by only a low wall from molten rock, and the inhabitants of certain villages celebrate the approach of a small lava stream with a fiesta, anticipating the money they expect to reap from sight-seers. Every generation or so, however, they are compelled to flee for their lives, and they may return to find their fields buried and their homes destroyed. An eruption of some violence and destructiveness is described in the following paragraphs.

THE ERUPTION OF VESUVIUS IN 1872[1]

For a number of months small lava flows had been becoming more numerous. On April 26, quantities of lava descended the cone, forming a splendid sight at night and attracting many visitors. On the night of the twenty-seventh a great fissure opened, from which a torrent of lava burst, burying a number of unwary spectators. At the same time a hail of burning projectiles from the crater killed others. Smaller lava flows exuded from other fissures, but did no damage. The large stream, however, dashed across the desert platform and down the lower slope, covering 1,300 meters (nearly a mile) in three hours. Then it divided into two streams, one of which overspread cultivated ground and country houses, while the other destroyed parts of two villages and invaded intensively tilled vineyards of high value. In a period of thirteen hours the lava occupied a surface of about two square miles.

About three-fifths of the lava did little injury, being deposited upon earlier unweathered flows. Nevertheless, even that buried the best quarries in the vicinity, and obliterated paths which had been cleared through the old flows with much labor. Many of the inhabitants of the devastated villages were unable to carry away any of their belongings, for even though their houses were not buried, the intense heat drove them precipitately away. From one of the villages the way of escape remained open, but a river of lava flooded the road to the other, cutting off the egress of those who had delayed flight in the hope that the flow would not reach them.

The lava ceased to flow in time to save the shore towns and Naples, but numbers of refugees had fled in terror from the mountain to Naples, and constituted a problem in housing and feeding for the authorities there. Indeed, not a few people from both the mountain and Naples went to Rome or to other distant points.

[1] Data selected from Luigi Palmieri, *The Eruption of Vesuvius in 1872*, translated by Robert Mallet. London: Asher and Co., 1873.

As the lava subsided, the ejection of bombs and ashes increased, and throughout April 28 and 29 the pine-tree cloud over the mountain became darker. Continual lightning and thunder played over the crater, but the thunder could scarcely be heard amid the crashing detonations of the mountain itself.

Almost always heavy rains have followed great eruptions of Vesuvius, and the muddy torrents which have coursed down the lower slopes have occasioned as much damage as the lava itself. In this instance the people were spared this form of devastation, although at midnight of the twenty-ninth a tempest burst over the district with loud thunder and a little rain.

During April 30 the volcano subsided, and by the morning of May 1, the eruption was over.

AN ERUPTION OF MONT PELÉE

In modern times Vesuvius has been far less destructive than other, less well-known volcanoes. One of the most devastating eruptions of recent decades was that of Mont Pelée, which effaced the city of Saint Pierre, Martinique, in a few minutes on the morning of May 8, 1902. Reliable eye-witness accounts of this outburst are wanting, but the following description of a subsequent eruption, observed by commissioners sent out by the Royal Society of London to study the volcano, gives a picture of the type of convulsion which had destroyed the city almost exactly two months earlier.

"As the darkness deepened, a dull red reflection was seen in the trade-wind cloud which covered the mountain summit. This became brighter and brighter, and soon we saw red-hot stones projected from the crater, bowling down the mountain slopes and giving off glowing sparks. Suddenly the cloud was brightly illuminated, and the sailors cried, 'The mountain bursts!' In an incredibly short space of time a red-hot avalanche swept down to the sea. We could not see the summit, owing to the intervening veil of cloud; but the fissure and the low parts of the mountain were clear, and the glowing cataract poured over them right down to the shore of the bay. It was dull red, with a billowy surface, reminding one of a snow avalanche. In it there were large stones, which stood out as streaks of bright red, tumbling down and emitting showers of sparks. In a few minutes it was over. A low, angry growl had burst from the mountain when this avalanche was launched from the crater.

"The time occupied by the avalanche to reach the sea was possibly a couple of minutes. It could not have been more. . . . .

"There is no doubt that the eruption we witnessed was a counterpart of that which destroyed St. Pierre. . . . . The most peculiar feature of these eruptions is the avalanche of incandescent sand and the great black cloud which accompanies it. The preliminary stages of the eruption, which may occupy a few days or only a few hours, consist of outbursts of steam, fine dust and stones, and the discharge of the crater lakes or torrents of water or mud. In them there is nothing unusual, but as soon as the throat of the crater is reached, a mass of incandescent lava rises and rolls over the lip of the crater in the form of an avalanche of red-hot dust. It is a lava blown to pieces by the expansion of the gases it contains. It rushes down the slopes of the hill, carrying with it a terrific blast which mows down everything in its path. The mixture of dust and gases behaves in many ways like a fluid. The exact chemical composition of these gases remains unsettled. They apparently consist principally of steam and sulphurous acid."[1]

Preceding the conflagration of May 8 there had been abundant warnings of unusual activity within the volcano, and thousands of persons had fled the city. Of those who remained, only one person, a prisoner in the city dungeons, was found alive. Reports gleaned from the few witnesses were so contradictory that few facts could be ascertained. These were set down by the Abbé Parel, Vicar-General of Martinique, who was one of the first to reach Saint Pierre after its destruction. He arrived May 8 at 3 P.M.

"Saint Pierre was a vast brazier of fire. Out [in the roadstead] blazes a great American packet, which arrived on the scene just in time to be overwhelmed in the catastrophe. Nearer the shore two other ships are in flames. The coast is strewn with wreckage, with the keels of the overturned boats, all that remains of the twenty or thirty ships which lay at anchor here the day before. All along the quays piles of lumber are burning. Here and there around the city, upon the heights and as far as Fonds-Coré, fires can be seen through the smoke.

"But Saint Pierre, in the morning throbbing with life, thronged with people, is no more. Its ruins stretch before us, wrapped in their shroud of smoke and ashes, gloomy and silent, a city of the dead. Our eyes seek out the inhabitants fleeing distracted, or returning to look for the dead. Nothing to be seen. No living soul appears in this desert of desolation, encompassed by appalling silence. When at last

[1] Quoted in the Smithsonian Institution *Annual Report*, 1902, pp. 342–343, Washington: Government Printing Office, 1903.

the cloud lifts, the mountain appears in the background, its slopes, formerly so green, now clad in a thick mantle [of ash] resembling an Alpine landscape in winter. Through the cloud of ashes and of smoke diffused in the atmosphere, the sun breaks wan and dim, as it is never seen in our skies, and throws over the whole picture a sinister light.

"In this desolation the troop of soldiers sent to the rescue could do nothing. We returned, utterly dispirited, to Carbet. New sensations and indescribable scenes awaited us there. Here, in a single house, are heaped up fifteen bodies. In another spot are dying men, horribly burned. Women and young girls, their flesh tumefied and falling into shreds, die as they reach the ship. Fathers mourn their children, wives their husbands. Many of these are returning from the country, ignorant, as yet, of the horrible truth. We wished to hide it from them, but they divined it. The cries which ring out break the heart. Many lost their reason.

"As a result of the loss of the chief magistrate of the colony, and of so many other civil and military officials, the Government is in a state of disorganization."[1]

A report of the eruption follows.

"Suddenly, at ten minutes of eight, a tremendous detonation resounded throughout the entire colony and an immense mass was seen bursting forth from the crater and hurling itself upward with extraordinary velocity. The black coils of the appalling column, rent by electric discharges, unrolled, expanded, and dissipated, and, impelled by an invisible force, moved on to discharge, at a distance, the incandescent matter contained within them. But suddenly, from the midst of these dense masses, a spout of fire detaches itself, beats down upon Saint Pierre like a hurricane, and envelops the entire city, its roadstead and suburbs, from the promontory of Carbet to Morne Folie, near Le Prêcheur, as if with the meshes of a horrible net. 'Everything went down before it,' said to me one who witnessed the sight from a favorable position, 'and at the same instant, everything took fire.' Deep night fell over the land, but it was immediately illumined by the dread fires of this veritable hell. From the grass of the meadows, from the crops of the countryside, to the great trees, to the houses and buildings of the city and its suburbs, to the very ships anchored in the roadstead, over earth and over sea, raged one vast conflagration, consuming thirty thousand human lives.

[1] Quoted in Angelo Heilprin, *Mont Pelée and the Tragedy of Martinique*, pp. 93–95, 100. Philadelphia and London: Lippincott, 1903.

"While the whirlwind of fire shot out by the crater moved towards the south and the west, increasing its destructive force and spreading its ravages, another phenomenon, worthy of notice, stopped it in its course. Two powerful atmospheric currents, laden with rain, held in reserve up to that moment by some unseen but providential hand, suddenly moved from the southeast and from the north, and precipitated themselves on both sides of the flaming spot. Circumscribing it with a clearly defined line, they cooled it to such a degree that we could see people about the line of demarcation struck on one side by burning missiles, while on the other side, and at a distance of only a few feet, nothing fell but the rain of muddy ashes and heated stones."[1]

Two days after the eruption, a party entered the ruined city. The following excerpts are taken from reports by the Abbé Parel and by the acting governor-general of the island.

"We find difficulty in reaching the Cathedral, as it is impossible to recognize the streets. The interiors of the houses, some of whose walls still stand, are blazing and smoking braziers. The heaps of stone, iron, lime, ashes, and rubbish of all sorts burn our feet. It is dangerous to touch the pieces of charred wall, which crumble at the slightest pressure. A large part of the victims are buried under the heaps of rubbish.

"We found bodies scattered everywhere, some of them distended by gases, and not carbonized; as to those who regained their homes, they seemed to us to be completely charred. It is impossible to penetrate into the interior and to reach the main street of the city, the Rue Victor Hugo. In fact, to do so would be to walk over a glowing brazier.

"From our examination of the ruined city, I conclude that the phenomenon which destroyed it was produced with such suddenness and intensity that there was no chance of escape; the ships in the roadstead, which were under high pressure, notably the two cargo-boats and the Girard-line steamer "*Diamant*," which had just arrived [from] Fort-de-France, could not evade it, and foundered or burned. The absence of any massing of bodies in the Rue Bouillé and the Place Bertin, a street and square surrounded by extremely populous houses, and the appearance of the bodies in an uncarbonized condition, obviously prove that no panic preceded the destruction; if it had been otherwise, the entire people would have hurried to the streets. Everyone died on the spot where he was overtaken by the cataclysm."[2]

[1] Heilprin, *op. cit.*, pp. 96–97. [2] *Ibid.*, pp. 101–102, 114–115.

Although in the past volcanic activity has been almost wholly destructive, efforts are now being made to convert the tremendous power of some of them into man's use. In a few places in Italy, and at one point in Chile, power is being derived from steam vents, which are associated with volcanic craters, and a movement is on foot to utilize in similar fashion volcanic force in Northern California.

ENGINEERING PROBLEMS AS RELATED TO THE DEPTH OF BEDROCK

The character of the material in which excavations have to be made gives rise to one of the major problems connected with construction.

Where a considerable thickness of unconsolidated material mantles bedrock, digging is easy, but excavations are likely to be unstable. Canals are subject to stoppage by slumping or creeping banks, bridge piers tend to be insecure, and heavy buildings may settle and become a menace to occupants and passers-by. The outstanding difficulty in building and maintaining the Panama Canal has proved to be slides in the Gaillard (Culebra) Cut. In cases where the bedrock is some hundreds of feet below the surface, as on extensive deltas, heavy bridges cannot be built. High buildings in a number of cities can be erected only after caissons have been sunk to solid rock and filled with concrete, to serve as supports; for example, in Chicago a large fraction of the cost of skyscraper construction is the expense of sinking foundations to bedrock, which lies at depths of 100 and more feet in parts of the business center. On the other hand, ordinary drainage ditches, small bridges, and the common types of buildings can be constructed quickly and cheaply, where excavation is altogether in unconsolidated material.

Where bedrock lies close to the surface, excavation entails blasting and consumes much time, although the work when completed is enduring. Canal floors and banks do not require retaining pavements or lining, tunnels need little or no reinforcement, and bridge piers and heavy buildings can endure exceptional strains. New York City, part of which lies on an outcrop of hard crystalline rock, has spent fabulous sums on tunnels under the rivers which surround the city, on subways, and on excavations for skyscraper basements.

BUILDING STONE

Stone has been used for building purposes throughout the ages. Building stone should possess as many as possible of the following qualities: (*a*) ease of cutting and shaping, (*b*) attractive appearance, (*c*) resistance to weathering and other wear, (*d*) permanence of color, or at least no tendency to stain when exposed to the weather, and (*e*) strength in sustaining weight. No stone possesses all of these qualities. In selecting stone for a particular use builders balance points *b*, *c*, *d*, and *e* against *a*. Passing styles have a great deal to do with the favor in which a particular stone is held, with the result that the value of certain quarries has risen and fallen sharply with changes in fashion.

Granite is difficult and costly to work, but it is very durable, and certain colors and textures of it are in demand for the street level portions of large buildings in cities. Limestones and sandstones vary widely in quality. The most prized limestone now used in the United States is that from the Bedford District of Southern Indiana. Bedford limestone is soft and very easy to saw and carve as it comes from the quarry, and its texture is smooth and its color a pleasing gray or blue-gray. Exposed surfaces of this stone harden with time and become very durable, and do not stain. Many limestones become streaked or spotted when exposed to the air. Most sandstones weather quickly, and their use for building purposes has therefore declined. Many once fashionable quarters of the Atlantic Seaboard cities were constructed of brown stone, a variety of sandstone, and many public and semi-public buildings in the Middle West were built of red standstone in the decades preceding 1900. Marble, which is an aristocratic and distant cousin to the common limestones, has special uses for fine interior finish and for a very few exteriors. Caen marble, of which many famous French chateaux and churches are built, is one variety widely used for exteriors, but it more closely resembles Bedford limestone than high-grade marble. Shale is too soft to be of value for building stone; conglomerate is difficult to shape properly; quartzite is so extremely hard as to be almost unworkable; most of the fine-grained igneous rocks are too hard to work satisfactorily. Glacial bowlders are striking because of their variety of shape, size, and color. Their use generally is confined to small structures.

MINERAL BUILDING MATERIALS OTHER THAN STONE

Whereas all peoples have lavished their labor, their wealth, and their ingenuity in constructing edifices of stone, ordinary buildings generally have been made of the humbler materials almost universally distributed throughout the earth's crust. Of these clay is most widely used, either in the form of sun-dried mud, known in many parts of the world as "adobe," or hardened by burning into brick or tile. Deposits of the requisite quality are common in most types of residual soils, in old alluvial soils, and in till. A special type of brick or tile, called terra cotta, is widely used for the facing of buildings because of its polished surface and its resistance to weather.

Within the past generation the art of making cement has been perfected. Prepared from limestone or from slag produced in the making of steel, cement serves to bind sand or gravel into hard rock called concrete. If set about a core of steel, concrete has not only the capacity to resist crushing, common to all rock, but also great tensile strength. These qualities, coupled with cheapness, the ease with which constituent materials may be transported, and the limitless variety of forms into which it may be cast, have brought concrete into favor for pavements, foundations, walls and floors, bridges, dams, breakwaters and piers, canal linings, and many lesser uses.

Sand, besides being a component of concrete, is the basis of the glass-making industry.

MINERALS AND POPULATION MOVEMENTS

All peoples in all ages have been drawn by an irresistible magnetism to the seat of minerals. The legendary gold of Ophir antedates historic record; tiny Phoenician vessels braved the stormy Atlantic and the savage tribes of Northwestern Europe, in order to gain the tin of Cornwall; aborigines of North America flocked to Central Ohio where an outcropping ridge of flint provided excellent arrowheads; and Americans of our own generation toiled over chill and mosquito-infested mountain passes to reach the gold fields of the Yukon Basin. It would not be unfair to say that minerals have marked the goal-posts of civilization in all ages.

Leaving out of account records of vanished peoples, the present-

day distribution of population reflects, in many striking instances, the attractive power of minerals. In the period before the development of intricate machinery and large-scale factory production, the most prized minerals were the precious metals, copper, tin (to alloy with copper in bronze), iron, and the precious stones. The web of European expansion can be traced in large part by following the paths of seekers for these minerals.

Back in the Middle Ages, miners from the ancient center in the Harz Mountains of Central Germany migrated to the Erzgebirge (Ore Mountains) of Southeastern Germany, where they helped found the state of Saxony, still an important member of the German confederation. Centuries later some of their descendants moved on into the Carpathians; there they set up tiny Saxon mining communities—little islands of Germans in a sea of Rumanians and Hungarians and Slavs —and there their descendants still live, still speak a German dialect, still profess the Lutheran religion, still carry on the tradition of Northern European culture.

In a somewhat different fashion the minerals of Spain have played a leading part in Spanish life. Copper, silver, and gold led Carthage to colonize the Iberian Peninsula, and when Rome conquered Carthage, Spain was one of the chief prizes. In the days of Arab glory, Spain fell into the hands of the Saracens, who utilized the mineral wealth. The swords of Toledo and Córdova have a peerless reputation. When the opportunity was offered of founding a new and vast Spain in the American continent, the dominant interest in mining among influential Spaniards focused their attention upon the silver and gold of the Mexican and Peruvian highlands, to the neglect of richer regions, the wealth of which was founded in agriculture. The more desirable part of North America was thereby left for the French, the British, and the Dutch, and the Pampas and Chile were greatly hampered in their development by the laws of the mineral-producing mother country.

When the factory system and modern transport grew up, the demand for certain minerals was greatly enhanced, because the number of products made wholly or in part from minerals increased, and because the quantity used was doubled and redoubled. Among the minerals which had had a long history, the increase in use of iron was by far the greatest, and by 1800 iron had come to occupy a front-rank position in the mineral world. But the factory system and modern transport was made possible by coal, an item of mineral wealth long known but scarcely used before the middle of the eighteenth century.

Coal made it both easy and cheap to generate steam, and today steam runs nearly all the wheels of commerce and of manufacturing. Coal likewise made it possible to smelt iron cheaply and to produce in quantity its various forms, chief among which are cast iron and steel. Hence leadership in the mineral world shifted from those regions long famous for mineral deposits to those regions possessing coal and iron. Of them the section of England lying between Birmingham, Liverpool, and Leeds was best endowed by nature. In relatively few years it was transmuted from a peaceful green landscape devoted chiefly to herding sheep, into a gigantic factory district, with chimneys belching greasy smoke, and myriads of toilers herded into tenements. The population grew so fast that the English "Midlands" shortly became more densely settled than the Southeast, which, from time immemorial, had been the principal center of English life.

Somewhat later, coal and iron centers in other parts of the world began to attract their respective populations. In North America, Pittsburgh, Pennsylvania, took its place as the premier steel center of North America, and, after the Civil War, Birmingham, Alabama, came into being as a counterpart of Birmingham, England. In Europe, the coal fields of Belgium and Northeast France turned that area into a humming hive, the most densely settled section on the continent. The mining tradition of South Germany was carried on by virtue of the coal and iron mined in Saxony, Silesia, and Bohemia. Germany's sudden rise to eminence among the nations during the decade 1860–70, and continued progress from that time until the outbreak of the World War in 1914, was due to many factors, but one of the chief was the rapid increase and enrichment of the population in the basin of the Rhine River through manufacturing and commerce. This development was related in a very fundamental way to the presence of coal in a number of places, particularly in the Ruhr Valley, and to iron in Lorraine and Luxemburg a close race for world-supremacy in manufacturing and trade. Germany felt, however, that the proximity of its coal and iron to France, constituted a danger to continued development, and therefore during the half-century preceding the World War, she made every effort to replace with Germans the French population along her western border. At the close of the World War, Germany having been defeated, much of her border territory, including most of the iron area, was handed over to France. In the post-war period French control was extended over the Ruhr District and its rich coal fields. In view of the important advantage which coal and iron gave

Germany before the war, it is easy to see why France should make every effort to handicap Germany's future development.

The multiplication of inventions which has resulted from and accompanied the factory system, has given a fresh impetus to the production of several of the long-prized minerals, and has created uses for many not utilized in earlier period of history. Various grades of steel require in their composition manganese, vanadium, tungsten, nickel, or chromium. Cheap production of sheet iron has made possible the widespread use of tin plate and galvanized iron, thus enormously increasing the consumption of tin and creating a market for zinc. But probably the outstanding metallurgical developments of the generation now passing have been the re-establishment of copper (the only practicable conductor of electricity available) to a place among pre-eminent minerals, and the introduction of aluminum as a commonplace. The other mineral development of first-rate consequence is the large-scale tapping of the world's petroleum deposits, and the establishment of oil alongside coal, iron, and copper, as a leading mineral.

To produce the minerals mentioned in the preceding paragraph, communities have been set up in such remote places and unfavorable environments as the Brazilian Highland, the Ural Mountains, Central Ontario, Southern Rhodesia, the Malay Peninsula, the Bolivian Highland, the Chilean Andes, the Belgian Congo, and the American Desert, and prospecting is going on in some of the most inaccessible places in the world, such as Alaska, the Amazon headwaters, and parts of the Sahara.

The foregoing sketch suggests that minerals have played an important rôle in movements of population, that pre-eminence in mineral production has enhanced national prestige and brought about economic and political supremacy, and that jealousy of mineral wealth has been instrumental in precipitating some wars. The compelling glamor of minerals lies chiefly in their highly speculative nature: the rich monetary rewards which result from successful production, whether the producer be a lone placer-gold miner, panning the alluvial deposits of a small stream, or a gigantic corporation controlling deposits in all parts of the world, employing thousands of men at high wages, undertaking outlays of millions of dollars before a penny can be expected in return, and marketing the product by way of its own transportation lines, its own factories, and its own selling organization. These rewards are so great that mining operations may profitably be undertaken in the most adverse climates and in the most remote localities.

ECONOMIC ASPECTS OF MINERALS

The mineral resources of the earth (aside from soil and water) differ enormously in value and utility, but they are similar in that their distribution bears little or no definable relationship to the other elements of the present-day natural environment (climate, land forms, water features, soil, plant life, and animals), and their formation is so slow that the supply, once exhausted, cannot be renewed in the lifetime of the human race. In these respects they differ from plants, to cite another of the earth's resources. Clearly, plant life is intimately related to climate, land forms, soil, waters, and in many cases to animal life. Clearly also, most plants grow in a span measurable in terms of a single human generation; indeed, most plants of economic value are annuals, and their continued production by man is, therefore, relatively simple.

The abundance and distribution of minerals profoundly affects their utility. Clay and sand are so widely and generously distributed that few places in the world lack either of them, and still fewer lack both. Hence, brick, tile, and the baser constituents of mortar and concrete normally are produced in or very near the place where they are used. Other building materials are widely, although not universally, distributed. These include gravel, stone suitable for crushing or for blocks, limestone for mortar and cement, sand from which glass can be made, and clay of the special sort required for pottery. Some finer materials, such as marble, slate, and first-class building limestone or sandstone, outcrop only here and there, and hence may be transported in small quantities hundreds of miles to their destination. The mineral fuels (coal and petroleum), and ores from which the metals of industry are derived, are more narrowly restricted in distribution than are most of the building stones. Still rarer are the precious stones and metals, which occupy the end of the scale opposite to plebeian clay and sand.

Although quantity in existence is one of the factors in the value of mineral products, it is by no means the only one. Certain of the rarer jewels, such as diamonds, sapphires, and emeralds derive a fictitious added value from their very scarcity. Wherever gold or silver is used as a standard of coinage, its value is arbitrarily fixed, and probably heightened, as well. The value of the commoner minerals is modified by the existence or lack of substitutes. Thus in recent years aluminum kitchenware has all but driven tinware out of the market. The uses and substitutions for most minerals are continually fluctuating so widely as to render the market highly unstable.

The cost of minerals is partly determined by environmental conditions at the quarry, mine, or well. Among these conditions the question of "cover" ranks high. By cover is meant the material which overlies the mineral sought. Where the paying mineral is exposed at the surface, or where only a few feet of soil covers it, open-pit mining is pursued. After the thin cover is stripped away, the rock, ore, or matrix is dug or blasted out. A familiar illustration is the ordinary stone quarry or sand pit. Nearly all building materials are procured from open pits. It is not so generally known that in favored localities other minerals outcrop over areas extensive enough to warrant open-pit production. The rich iron ore of Northeastern Minnesota, many of the copper mines of the Rocky Mountain Region, and the Kimberley diamond mines are of the quarry (open-pit) type. Where the cover is so thick that shafts must be sunk, the character of the rock of which it is composed is of utmost importance. If it is substantial and resistant to pressure and decomposition, the gallery roofs need little propping; if the cover is weak, the most careful propping is but scanty insurance against cave-ins, which may result in loss of life to miners, and destruction of buildings and even farmland on the surface above. In any event, the cost of production in shaft mining is much higher than the cost of open pit mining. In some situations, streams have cut valleys through both the cover and the vein of mineral. Where this has occurred, galleries may be driven in from the valley sides along the veins of ore, thus eliminating the cost and danger of lifting men and materials through a shaft. Some of the coal mines of Western Pennsylvania furnish striking examples of galleries driven laterally from valleys, and small mines of this type, particularly coal mines, are rather widespread.

Placer mining is carried on where remnants of a valuable mineral are scattered through an alluvial deposit. In a few cases, as with the diamonds of Southwest Africa, the stones are associated with wind-blown deposits; generally, however, the stones, or nuggets, or flakes, or dust are buried in the soft material of stream-laid deposits. Some of the most famous gold finds of history have been placer deposits, among them California in 1847, and the Yukon in 1897. The first diamonds of South Africa were discovered on tributaries of the Orange River. The notable tin workings of the Malay Peninsula are placers. Placer mining, unlike shaft, or even open-pit mining, may be carried on by individual effort, with no capital other than a pan, for in essence it consists in sorting the deposits. Since most metals are heavier than the minerals of common rocks, in panning, the valuable mineral remains

after the dross is washed away. At the same time, given adequate capital, placer mining can be carried on by means of huge dredges which sort tons of material in a day. Hence, placer mining may be lucrative to individual laborers or to corporations with large investment in machinery.

The richness of an ore is important in determining cost of production, and under conditions of world-wide competition, ores carrying less than a certain percentage of mineral cannot be mined. For a metal as common as iron, ore of less than 40% ordinarily is not worth mining. Copper, in contrast, has been produced profitably from ore running as low as 1%. In many places two or more metals are produced from the same ore. Under such conditions the percentage of each may be lower than where a single mineral must bear the cost of production.

The chemical form in which minerals occur also affects their utilization. For instance, iron associated with phosphorus is unsatisfactory for making steel; hence ores low in phosphorus are prized.

Finally, the cost of production at the mine varies with climate. Where minerals are found in regions having a climate unsuitable to the hard physical exertion common to most mining, the miners demand high wages, or short shifts, and in some cases labor must be drawn from population groups which are acclimated. In the numerous mines of the Andean Plateau, only natives, whose lung capacity is large, can work hard in the high altitudes; the tin mines of Malaya are manned by natives or by coolies from the warmer parts of China. Less direct, but just as potent, is the effect of climate on the food supply. Wherever a mining district lies in a region of climatic extremes, the production of foodstuffs is restricted or precluded. This necessitates importation of food, and the cost of transportation must be added to the price of the mineral for the sake of which people are abiding in the wilderness. The short growing season of high latitudes makes it necessary to haul food long distances to the coal mines of Spitzbergen or the gold mines of the Yukon; the low temperature of high altitudes, such as the Andean Plateau, has the same effect, relative nearness to food-producing regions being offset by the high cost of transport over steep slopes. Scarcity of rainfall trammels mining operations. Deep wells or long and costly aqueducts may be necessary; in the nitrate desert of Chile and the diamond mines of Southwest Africa, water must be imported in ships or distilled from sea water.

The transportation of minerals to regions populous and progressive

enough to use them is a serious problem in many cases, for rich deposits are as likely to occur in out-of-the-way places as in well-settled regions. Thus coal is found in Spitzbergen and the Middle Rockies, gold on the Yukon, in South Africa, and in desert Australia, copper in the desert mountains and plateaus of Western America, nitrates in the barren and remote low latitude desert of Western South America, and iron, copper, silver, nickel, and arsenic in the ice-scoured Laurentia.

It often happens that mining communities are separated by many miles and untold hardships from the outside world, and it is not surprising that the inhabitants of such communities are restricted to the few coarse recreations possible in remote and frontier places.

Where the mineral wealth justifies a permanent settlement, improved transportation after a time puts the district in closer touch with the world at large, and the more orderly and normal life of settled communities gradually supersedes the hectic excitement of the mining camp. Nevertheless, mining towns rarely become permanent, except where some other occupation, such as manufacturing or trade, gets a start. It is a common occurrence for a mining town to dwindle from twenty or thirty thousand inhabitants to none, in from 5 to 10 years after the mineral which gave it birth has been exhausted.

THE CONSERVATION OF MINERAL RESOURCES

The supply of some minerals so far exceeds their present or prospective use that for all practical purposes it is unlimited. At the opposite extreme is a group of minerals which are being used so rapidly in proportion to known or probable deposits that exhaustion is immanent. Between these extremes are a number of minerals which occur in abundance, but which are being used so rapidly that they may become used up in the course of a few hundred years.

Estimates of the reserve supply of any mineral are mere guesses, both because the deposits are out of sight, and because in many regions careful prospecting has not been carried on. Furthermore, estimates of future probable use involve so many variable factors that nothing more than the general order of duration of reserves can be agreed upon. In the table at the end of this section the principal minerals are grouped more or less arbitrarily into three classes.

In recent generations most of the minerals in the second and third classes have been subjected to unwise use and to waste. This has led to a vigorous movement for their conservation. The supporter of conservation does not oppose the free *use* of any mineral, but he holds that this generation has no moral right to *waste* a resource which will be of value to succeeding generations. For instance, he decries the custom, once prevalent, of permitting natural gas to burn throughout the day, just because of its extraordinary cheapness. This position would seem to be the only one tenable for a person who is interested in human welfare.

CLASSIFICATION OF MINERALS ACCORDING TO SUPPLY

Unlimited Future Supply	Sufficient Supply for Some Generations	Scanty Supply, Exhaustion Immanent
Clay, sand, lime	Coal	Petroleum
Building stone	Copper	Natural Gas
Salt	Zinc	Nitrates
Iron	Lead	Phosphates
Ores of aluminum	Potash	Tin
Gold, silver		
Precious stones		
Most of the rare metals		

VIRGINIA CITY, A MINING CAMP[1]

Prospecting for gold in Western United States led to the discovery of a lode of silver ore in West Central Nevada in 1859. No place could have been more unpropitious for community existence. On three sides the desert stretched unbroken for hundreds of miles. The abrupt and lofty Sierra Nevadas marked the limit of the desert a few miles to the west, but it formed a barrier with high passes which were blocked by snow through a long winter, and which communicated only with the frontier posts of California even in summer. The site lacked timber, food plants, and even water. Nevertheless, prospectors began

[1] Data selected largely from Eliot Lord, *Comstock Mining and Miners*, Monograph IV of the United States Geological Survey. Washington: 1883. Quotations are all from this source.

to flock to the camp as soon as the discovery was announced in the California papers, late in July, 1859.

In October a single street was laid out along the lode, and on it two houses of crudely cemented stone, and straggling lines of flimsy huts and tents were promptly set up. "Tents of dirty, ragged canvas pieced out with tattered clothes coated with grime; hovels of pine boards roughly nailed together and pierced by bent and rusty stove-pipes; heaps of broken rocks with shapeless crevices into which men crawled like lizards; shallow pits partly covered over with boards and earth—these were the winter homes of the citizens." The winter proved to be a severe one, and between icy gales and sifting snow on the one hand, and insufficiency of shelter, firewood, and food on the other, many men suffered severely.

Provisions were low when the first pack train reached the camp on March 31, 1860, after a tedious and difficult trek over the mountains. "The gaunt, liquor-laden mules were welcomed by the thirsty miners as well-springs in a desert are hailed by weary travelers. They could scarcely wait while" the stores were unpacked and a tent was put up. "A canvas partition divided the tent into bar-room and lodging room, and [a] new hotel was then open for guests. The side-board of an emigrant wagon served as bar counter, resting on stakes driven into the ground. When the precious liquors were at last ranged beside the bar an irresistible rush was made toward the counter, and the customers drank faster than they could be served." The remainder of the stock consisted of blankets and tin plates. Everything sold at fabulous prices, which were only slightly diminished by the arrival of other trains, because the camp grew so rapidly that the demand for equipment and provisions continued to exceed the supply. It is said that in September, 1860, besides numerous pack trains, 450 wagons were in the service across the mountains, in spite of the fact that the road was hardly passable for wagons. It took from twelve to twenty days to make the round trip.

Two more lanes of shanties were laid out during the summer of 1860. "A restless crowd blocked these narrow passages, flowing in and out of their bordering saloons and gambling houses. The cheerless hovels were deserted for these lighted rooms, the real homes of the citizens." Many of these men were bona fide prospectors, but many others were mere adventurers who contrived to subsist by borrowing and gambling. All indulged in a riot of speculation, based on the hoped-for profits from the lode.

"The working miners had few pleasures except the unfailing resources of gambling and drinking. Courtesans promenaded the streets, decked out in gay dresses and showy jewelry. Saloons of all descriptions, from the spacious rooms furnished with walnut counters, massive mirrors, and glittering rows of decanters, to the cheap pine bar with its few black bottles, were to be found on every street and lane corner." The first theater was opened in September, 1869, and attracted crowds of the restless miners, in spite of the mediocrity of the performances.

The camp was fast becoming a town: tents were replaced by board cabins, and there was a surprising number of business houses and offices, including 38 stores of general merchandise, 25 saloons, 9 restaurants, 8 boarding-houses, 10 livery stables, and some 70 others. In one lodging-house a man had to pay $1 a night for a wooden bunk with hay tick, in a room 20 feet by 12, which he shared with 17 others. The population at the close of the year is estimated to have been 2,844.

In 1861 the settlement obtained a charter of municipal government from the legislature of Utah, of which territory it formed a part, and in 1864 it was chartered by the state of Nevada, the admission of which to the Union had been made possible by the growth of towns on and along the route to the silver lode.

In the next few years mining corporations supplanted prospectors, and roads were built to California. By 1865 the population was about four times the figure of 1860, the town had been subdivided into wards, streets had been graded, and the two business streets were distinguished by substantial buildings of wood and brick before which wooden platforms had been laid, forming a kind of sidewalk. The population had begun to segregate into quarters. In the upper streets lived the mine superintendents and the wealthier merchants and professional men. At the base of the hill was the Chinese quarter. The Chinese performed the labor despised by all other groups—washing, cooking, gathering firewood, and doing domestic service in the richer homes. Their section was marked by neat storehouses, curious trinkets, packed dormitories, and "the pervading sickly odor of burning opium." Nearby stood "two rows of white cabins with gaudily furnished rooms, at whose uncurtained windows sat women of the town." This quarter was marked out by law. Below the Chinese section lived the Indians. "Gambling and eating [were] their occupations: work an unpleasant interlude," confined mostly to sawing wood or picking up sticks under the stimulus of an immediate bite of food or draft of whiskey. And

"everywhere—among the business stores and the Chinese laundries; among the residences of wealthy citizens, high up on the mountain side, and the cottages of the harlots on the lowest street—were the drinking saloons. The movement in and out of these saloons and along the principal streets was like the circling tramp of a tiger snuffing at bar after bar of his cage. Perhaps this was because the city, set in a desert, had something prison-like in its encircling wall of barren hills, and few thought of straying beyond its circle of lights."

As the city began to take form, it became more and more self-supporting. Salt was brought from nearby accumulations in the desert, and copper and soda for use in the mining operations were procured in the vicinity. Bricks were manufactured locally, and a municipal gas works was installed, the works and mains having been shipped from Philadelphia. Schools and churches were built. Newspapers began publication.

By 1870 a consolidation of several important mining interests seemed to assure the district a long lease of prosperity. Nevertheless, further operations were threatened by ground water, which poured into the shafts and filled the galleries. These difficulties were removed by the construction of a drainage tunnel, completed in 1878, which cost $4,500,000. Its success was attested some years before its completion, and resulted in an increased boom, which reached its peak in 1876. In 1880 the population of the lode towns aggregated 16,000, although it is estimated that 20,000 was reached in the years just preceding. Virginia City alone numbered 10,900 inhabitants. The now considerable city was supplied with water by a tunnel which tapped a lake in the Sierra Nevadas, thirty miles away, and with ice from the reservoirs of the water system. The cost of this project was nearly $2,500,000.

After 1880 the silver mines of this region were affected by the decline in the price of silver, and by the increased cost of mining as the shafts had to be sunk deeper and deeper. The lode cities shrank almost as rapidly as they grew. In 1890 the population of Virginia City was 8,500; in 1900, 2,700; in 1910, 2,250; and in 1920, 1,200.

CHIEF STEEL-PRODUCING COUNTRIES, 1923[1]

	Million Tons
United States	45
United Kingdom	9
Germany	6
France	5
Belgium	2

CHIEF COPPER-PRODUCING COUNTRIES, 1923[2]

	Thousand Metric Tons
World	1,266
United States	651
Chile	203
Africa (chiefly Belgian Congo and Rhodesia)	74
Japan	64
Mexico	55
Spain-Portugal	52
Peru	44
Canada	36

UNMINED COAL RESERVES OF THE WORLD[3]

	Billion Metric Tons
World	7,398
United States (half lignite)	3,527
China	996 to 1,500
Canada (three-fourths lignite)	1,234
Germany (including Silesia 166 and Saar 17)	423
British Isles.	190
Siberia (largely lignite)	174
Australia (chiefly New South Wales)	166
India	79
Russia	58
South Africa	56

No other country possesses as much as 50 billion tons reserve.

[1] *The Mineral Industry During 1923*, p. 356. New York, 1924.
[2] *Ibid.*, p. 170. New York, 1924.
[3] Spurr: *Political and Commercial Geology*, pp. 24–29. New York, 1920.

CHIEF COAL-PRODUCING COUNTRIES, 1923[1]

	Million Metric Tons
World	1,337
United States	578
United Kingdom	283
Germany	189
France	38
Poland	36
Japan	28
Czecho-Slovakia	28
Belgium	23
China	21
India	19
Canada	15
Australia	12
Russia	12
Union of South Africa	11

CHIEF PETROLEUM-PRODUCING COUNTRIES, 1923[2]

	Million Barrels
World	1,009
United States	733
Mexico	149
Russia	38
Persia	25
Dutch East Indies	15
Roumania	11

[1] *The Mineral Industry During 1923*, p. 143. New York, 1924.
[2] *Ibid.*, pp. 494–495. New York, 1924.

THE ARTESIAN WATER SUPPLY OF EASTERN NORTH AND SOUTH DAKOTA[1]

Eastern North and South Dakota possess a rich resource of artesian water. This is derived from deep wells (there are perhaps sixteen or eighteen thousand in all), in which the water rises notably, and in many cases flows out at the surface of the ground.

The source of nearly all of this water is the Dakota sandstone, a porous stratum of rock averaging more than a hundred feet in thickness. This "water-bearing" layer lies deep under the Great Plains, but comes to the surface in the form of a ridge girdling the Black Hills, and in the foothills of the Rocky Mountains, where it receives water both from rainfall and from surface drainage. Under the plains, this sandstone stratum is overlain by relatively impervious rocks. Along the Dakota River the sandstone is reached at depths varying from 200 feet near Mitchell to 1,500 feet near Aberdeen. West of the Missouri River in South Dakota there are several wells more than 2,000 feet in depth.

A glance at a map will show that most of the wells are hundreds of miles from the districts where the porous layer outcrops; but that the intake for the water is many hundred feet higher than the surface of the country in which the wells have been drilled. Thus the water in the deep lying sandstone stratum under the plains is under pressure and rises in the wells. Where the wells flow there is no cost for pumping, and a well may yield a bountiful supply of pure water for years with no expense beyond the original cost of drilling. Pressures as high as 200 pounds to the square inch have been recorded at some of the Dakota wells. Even where the pressure is not so high, the flow may be copious. The largest well in the area is at Aberdeen. Its flow of 2,000 gallons a minute (more than 100,000 barrels a day) is sufficient to supply a city of 15,000 inhabitants.

Nearly all the cities and villages in the artesian area now secure their water supply from artesian wells, and both towns and rural districts generally are supplied with running water for buildings, gardens, and lawns. Artesian water is extensively used for watering live stock. The animals prefer it to ordinary well water because it is

[1] Based mainly on S. S. Visher, "Geography of South Dakota," *South Dakota State Geological and Natural History Survey*, Bulletin No. 8. Vermillion, South Dakota, 1918. Some data from Water Supply Paper 520-E, United States Geological Survey, Washington, D.C., 1925.

much warmer than the air in winter and much cooler than the air in summer, and probably also because of its mineral content.

The widespread drilling of artesian wells in the Dakotas is relatively recent. The first well was put down at Aberdeen, South Dakota. Until about 1898 the cost of construction was beyond the means of most farmers, and nearly all the wells have been drilled since the turn of the century.[1]

The water supply thus procured is convenient, abundant, wholesome, and inexpensive. Formerly it was constant, but many wells yield less than formerly, and the flow from some has ceased. Although some of these cases may be accounted for by clogging or faulty construction, the decreased flow seems to be due mainly to depletion at a rate faster than that of replenishment, of the water stored up through the ages. In 1922 the total yield was only one-fourth as large as in 1912, although there were two and a half times as many wells. This shrinkage seems to have been due to waste, rather than to use. It is estimated that 90% of the aggregate flow has been allowed to run to waste, simply because it was more trouble to cap the wells than to let them flow. In an effort to avert destruction of the resource the state governments are now taking measures to conserve the supply.

SPRINGS

No natural features vary more from place to place in occurrence, characteristics, and utility than springs. They are perhaps of greatest significance in deserts, where their location and flow is of prime importance. Trails across deserts in most cases lead from spring to spring, and the length of a day's journey largely depends on the distance between "water holes," which in more instances than not are springs. The most serious thing about getting lost on a desert trail is the resulting danger of missing water holes. Rather frequently, but at unpredictable intervals, desert springs may dry up, causing discomfort and even peril to travelers. The size, flow, and location of desert springs vary infinitely. A common situation is the base of cliffs which border mesas or plateaus, from the surface of which the

[1] The cost of construction in the 1880's averaged more than $2.50 a foot, whereas in 1918 it ran about $0.50 a foot.

water of infrequent rains seeps downward and outward. Another common situation is in a valley down-stream from the point where a stream disappears in its permeable gravel bed. Some springs, in both arid and humid regions, are in effect natural flowing wells in which water under pressure in an underlying porous stratum is forced up to the surface through cracks or fissures in the overlying rocks. Probably no deserts are entirely without springs, but in some arid regions, such as Southern Arabia, the scarcity of watering-places almost prohibits travel. In the arid parts of Western United States the United States Geological Survey has begun the very useful work of erecting guides to watering-places.

Springs in many humid regions constitute an important source of water for domestic uses. In not a few areas during the period of early settlement, springs were considered essential to a home site. In the hill country of Southwestern Wisconsin, for example, most early settlers located their houses in valleys near springs, and extensive upland areas without springs remained unsettled for some time, in part because of their lack of a ready water supply. Presently, with the introduction of well-drilling machinery and pumps, a satisfactory water supply was obtained on such upland areas, and the necessity of a spring near a home site disappeared.

In the older settled areas of Western and Central Europe and Eastern United States, the reason for the location of many towns and villages can be traced back to large springs of good water, although most of these springs many years ago ceased to supply the needs of the growing communities. An exceptional case of a large community getting its entire water supply from a single spring is that of Johnstown, New York, the population of which is 10,000 or more.

Most springs are pure because the water becomes filtered on its long journey through the rocks and soil. In some cases, however, spring water is contaminated, and it is an excellent practice to scrutinize the probable purity of springs as closely as that of wells.

More or less mineral matter is dissolved in the water of all springs. The amount varies with the character of the material through which the water has seeped, the length of time the water has been percolating through the soil and rocks, and the temperature and mineral composition of the water as it seeps through the rocks. The mineral most commonly present in quantity in ground water is lime. Water containing considerable lime is said to be "hard." The use of hard water is costly—it requires extra soap, and when boiled it deposits a coating

of lime on kettles and boilers. To boil water in vessels or tanks which are furred with lime wastes heat, and occasionally the deposit has to be scraped out.

If iron, sulphur, or some other mineral is present in noticeable quantity, a spring may be called a "mineral spring." Most mineral springs have no especial medicinal value, and much money has been paid for harmless but quite inefficacious spring waters.

A special variation of mineral spring is the hot spring, the waters of which well from the surface of the ground at a temperature above body heat. Many hot springs have occasioned the establishment of baths and associated resorts to which people flock, either for treatment or for the luxury and relaxation of resort life. Not a few of these resorts are internationally famous, among them Hot Springs, Arkansas, Hot Springs, Virginia, Wiesbaden, Germany, Carlsbad, Czecho-Slovakia, and several springs in Japan. Where hot springs take on a beautiful or fantastic appearance, or where they spout forth at intervals in the form known as geysers, they become a magnet for tourists. The Yellowstone National Park in the Northern Rocky Mountains, and the geyser basins of Iceland and New Zealand are the principal groups of hot springs of these types.

TYPES OF GROUND-WATER OCCURRENCE

Little is known of ground-water conditions throughout most of the world, but presumably the following discussion of selected areas in the United States typifies the major modes of ground-water occurrence everywhere.

Ground-water in recent sediments.—Material deposited during the most recent geologic age contains more water than all the older formations put together. This is owing partly to the position of recent sediments on the surface, where they receive the rains, and partly to the fact that they are uncemented or only slightly consolidated, and therefore contain maximum pore space.

Alluvial deposits run the gamut in water-yielding capacity. Clay is almost impermeable and gives up its water extremely slowly. Gravel, at the opposite extreme, is the most permeable material found in the earth's crust, and yields its store of water rapidly and completely. All ordinary stream alluvium contains lenses and stringers of gravel and coarse sand, which furnish an abundant supply of water to shallow

wells. The stream valleys of the Atlantic and Gulf Coastal Plain illustrate this source of domestic water supply.

The piedmont plains of Southwestern United States are built up of coarse alluvium which is of utmost value to the inhabitants of that section as a source of water, not only for domestic uses, but also for irrigation.

Over the moraine plains of Northern United States and along their margins vast quantities of alluvium were rudely assorted and laid down as valley trains and outwash plains bordering the ice sheets. Glacial outwash contains a higher percentage of gravel and coarse sand than ordinary alluvium, and hence forms an abundant source of water. Not only are farms and villages able to supply themselves from underlying outwash, but also cities of considerable size find adequate stores. Until the completion of the Catskill Aqueduct (in 1916), Brooklyn, New York, derived its municipal supply from the glacial outwash which forms the southern half of Long Island. Many cities in valleys of the unglaciated Middle Mississippi Basin draw their water supplies from glacial outwash which extends into the region from the glaciated area.

Glacial till provides water for domestic use throughout Northern United States. Because of its heterogeneous texture, till varies widely as a water-bearer. Where it is sandy throughout, satisfactory yields may be obtained from wells dug or drilled almost anywhere. Even where clay till predominates, lenses of sand or gravel are scattered through it and serve as reservoirs, adequate to the needs of individual farmers and villagers. In earlier years dug wells were relied upon. These were 2 or 3 feet in diameter, 20 or 30 feet deep, and shored up with stone. They were likely to be polluted by sewage, and as more wells were sunk the water table was lowered and the wells were prone to go dry. Nowadays most farm wells in the moraine are drilled to the surface of bed rock, which serves as a more or less impervious floor upon which the seeping water collects. Such wells are a few inches in diameter, and are cased with iron pipe which minimizes pollution. Almost any well in ordinary till can be pumped temporarily dry in a few hours by a windmill.

Loess, being fine grained, yields meager quantities of water, so that wells usually are sunk through it into outwash, till, or bedrock. An excellent example of this is the unglaciated area of the Upper Mississippi Basin, where the uplands are covered with loess, and the wells are sunk into the bedrock below.

Ground water in sedimentary rock.—Just as alluvium varies in

yield of water with texture, so rock made of cemented sediments ranges from highly pervious sandstone to practically impervious shale, with limestone occupying an intermediate position. As a rule the porosity of any given type of rock decreases with age. Thus the relatively recent and but slightly cemented sandstones of the Atlantic and Gulf Coastal Plain are generous water-bearers, with a yield approaching that of sand and gravel. These strata outcrop in bands roughly paralleling the coast, and along the exposures shallow wells may suffice. Where the beds dip under impervious strata they are tapped by deep drilling; many of these drilled wells are artesian.

The older sedimentary rocks of the Middle Mississippi Basin yield meager amounts of water, and that furnished by deep-lying strata is so salty or otherwise mineralized as to be unfit for domestic use. Much of this region is underlain by limestones, which carry most of their ground-water in caverns dissolved out of the rock. In many places these caverns afford storage space for much water, some of which finds its way to the surface as copious springs. But cavern water is highly mineralized below the level of surface drainage. The people of this region are forced to depend chiefly upon springs or shallow wells tapping the mantle soil.

The ancient sedimentary rocks which underlie the moraines of North Central United States are utilized wherever the supplies from till and outwash prove inadequate. This generally occurs in the case of cities ranging from 10,000 to 100,000 population—with numerous factories making heavy drafts on the municipal water system, in addition to the demands of up-to-date ideals of sanitation. Many of these cities have bored deep wells to tap sedimentary rocks which will yield water. In valleys these are likely to be flowing wells. The principal water-bearing strata are sandstones, which yield water mineralized to the point of being hard, but not objectionable to the taste. In some places cavernous limestones are tapped.[1]

The total volume of water derived from deep strata is far less than that procured from surficial sediments, and already there are indications that the rock is being drained. Cities of only a few thousand population in Central and Southern Illinois are faced with the necessity of developing a domestic water supply from surface sources, and continued growth of congested urban centers bids fair to compel general

[1] Since carbon dioxide drawn from the air is required for the solution of limestone, deep-lying strata rarely are cavernous. But in this region the caverns were made in preglacial times, when the limestone lay at the surface, uncovered by till.

abandonment of underground sources of water. Wells of greater depth will not solve the problem, because rocks at depths of more than 2,000 feet contain little water, or else water excessively and unpalatably mineralized. This is true, not only within the region under consideration, but generally throughout the world. Most mines are dry below 1,500 or 2,000 feet, even where the rock is permeable, and most very deep wells, sunk for petroleum and gas, are waterless in their lower reaches. This is true of the two deepest wells in the world (7,579 and 7,386 feet respectively) although in another scarcely less deep, water was found 6,260 feet below the surface. In Western South Dakota water is abundant in sandstone 3,000 feet deep, and in Australia a number of wells more than 4,000 feet deep are in constant use; but these cases are marked exceptions to the rule.

Ground water in recent lava.—Lava poured out on the earth's surface is full of cracks and contains numerous caverns. The cracks are caused by cooling, and the caverns result where the surface solidifies and permits underlying molten rock to flow away. Where such lavas are geologically recent, these spaces have not had time to fill with precipitated mineral matter, and many hold abundant supplies of water. Such is the case in the Columbia Plateau, where successive sheets of lava of this type, interbedded with sand, gravel, and ash, provide room for large quantities of water. The region is noted for its many capacious springs and for abundantly yielding wells.

Ground water in ancient crystalline rock.—Except for recent extrusive lava, crystalline rock is notoriously poor in ground water. The individual crystals of which it consists fit snugly against each other, leaving little interstitial space. In the case of very ancient rock even the cracks and joints are more or less plugged up with precipitates of solid mineral matter. These conditions are exemplified in the ice-scoured country of old crystalline rocks of Eastern Canada, which extends into the United States at the head of Lake Superior. The fact that this particular region of ancient crystallines has been ground down by ice-scour so recently as to expose a fresh, solid surface, stripped of a disintegrating mantle of soil and devoid of large cracks heightens its impermeability. Nearly all the water lies within 300 feet of the surface, and little is to be obtained within that zone. Patches of till scattered over the area are too thin to serve as important reservoirs for water.

Where ancient crystallines are buried beneath a thick mantle of soil produced by weathering, shallow wells yield some water, as do

also somewhat deeper borings, drilled into the cracked and jointed rock immediately below the loose mantle. This is the case on the Piedmont of Southeastern United States. Where such rocks are covered with a thick layer of glacial till or alluvium, the surface of the bedrock forms the horizon of maximum water yield.

Ground water in mountains.—In mountainous and hilly regions, conditions are peculiarly favorable for springs where mantle rock merges into bedrock on valley sides, along bedding planes or joints, and at exposures of porous rock strata. Limestone in mountains is likely to be cavernous, and from such strata large springs gush forth, each heading a creek of goodly size. The Balkan Peninsula is famous for springs of this type.

Wells are not much needed in mountainous districts, owing to the abundance of springs. Shallow wells in the alluvial gravels of the valleys encounter abundant supplies of water.

SURFACE WATERS AS SOURCES OF CITY WATER SUPPLY

Drinking water is essential to human life, and the distribution of population is intimately tied up with water supply. In some sparsely peopled districts springs furnish all the water needed, and each habitation is located as near as possible to a spring. In most regions, however, it is more practicable to dig wells at sites otherwise suitable for dwellings than to depend on springs, which may be inconveniently located. Farms and small communities generally can be provided with ample water for drinking and other domestic uses by springs or wells, sometimes supplemented by cisterns of rain water. Cities, on the other hand, are likely to require more water than can be supplied from these sources, partly because of the large number of individuals using water, and partly because of additional uses for water, such as cleaning streets, diluting sewage, and consumption by manufacturing plants. In the case of very large cities the problem of water supply becomes acute and demands solution at no matter what cost. The solution worked out by the world's large cities varies with conditions of the environment. In the following paragraphs consideration is given to the contrasted ways in which a number of representative cities have solved the problem of water supply.

London, the largest city in the world, has procured its water supply from a variety of sources. In the Middle Ages water was obtained from the Thames within the city, from local springs, and from shallow wells dug in the gravels in the valley bottoms of numerous little streams which once flowed into the Thames. As the population grew, these sources became polluted, the streams became sewers, and water was piped in from springs some miles from the city. A project completed early in the seventeenth century brought a supply through a channel $38\frac{3}{4}$ miles long from copious springs in limestone which outcrops 20 miles north. Subsequently other projects brought water from rural districts on all sides of London. For a long time it was supposed that no supply could be derived from wells sunk within the city through the polluted gravels, because the whole London Basin is underlain by impervious clays which yield little or no water. Finally, however, it was discovered that wells 300 to 700 feet deep reached a copious artesian supply from a limestone stratum which outcrops all around London from 8 to 20 miles outside the city borders. During the nineteenth century so many wells were bored to tap this water-bearing stratum that the supply was depleted. A number of wells now are dry and from the others the water must be pumped up the last 200 to 300 feet. In recent years a second impervious layer of earth has been penetrated by wells more than 1,000 feet deep, and under it a second artesian supply has been tapped, this time in sandstone. The water is somewhat salty, but it may be used for a number of manufactural purposes. There are more than one thousand artesian wells in use in London today. Nearly all of them are privately owned, and serve factories, hotels, and large downtown buildings.

The public water supply of London is derived from surface waters, controlled by a municipal commission. This commission has authority to use the waters of 559 square miles of the drainage basins of the Thames and the Lea (a tributary which enters the Thames in the eastern part of the city). Storage reservoirs have been built capable of impounding nearly twenty billion gallons, of which the Thames basin provides about two-thirds. Because of the small volume of the streams which furnish the water, there are many reservoirs—thirty-two along the course of the Thames, and a number more along the Lea. All this water must be carefully purified, because it is drawn from an intensively farmed district where much fertilizer is used.

With continued growth of population, the problem of procuring

sufficient water has been solved repeatedly, only to reappear after a few years. The several supplies now being utilized are dependent upon local rainfall, principally that of the winter season. Even now a dry winter is succeeded by a season of shortage. This has led to proposals to procure an additional supply from the Welsh Hills. There the annual rainfall averages three times that of the London district, and because of the crystalline rocks which underlie the region, the run-off is rapid and readily available for diversion to city needs. Moreover, these hills are so sparsely populated that pollution is negligible. Already, Liverpool, Birmingham, Cardiff, and Swansea procure their water from reservoirs in Wales.

The present water supply of London is summarized in the following table:

Source	Approximate Percentage of Total Water Supply	Approximate Percentage of the Population Served
Thames	59	56
Lea	23½	25
Springs and wells	17½	19

Nearly all very large cities lie on streams. Where the streams are small, as in the case of those above London, the supply of water is likely to be deficient. Where the streams are large, however, the supply is abundant, but it is likely to be muddy and disease-laden. St. Louis, Missouri, on the Mississippi River a few miles below the mouth of the Missouri, illustrates this type of river location. Because of the large volume of the stream, no storage reservoirs are necessary, and a single intake suffices for the city's requirements. This intake is located above town, whereas the sewage is emptied into the Mississippi at the lower end of the city. Nevertheless, sewage from cities and towns above St. Louis on the main stream and its tributaries pollutes the water at the intake, and necessitates chemical treatment and filtration to improve its color and healthfulness. Because there are no large cities for 250 miles up the Missouri, whereas the Mississippi is dotted with cities and receives the sewage of Chicago as well, most of the St. Louis water is taken from the western side of the Mississippi, which carries the flow of the Missouri practically unmixed throughout most of the year. During low water of late summer, however, the flow of the Missouri falls off so much that upper Mississippi water constitutes most of the flow of the stream at St. Louis. The Missouri

water is exceptionally muddy, and one of the principal improvements in the city supply resulted from the discovery of a chemical process to precipitate most of the sediment. The death-rate in St. Louis has declined sharply with every improvement in the clarifying of the water, and now the supply is satisfactory, except that it is rather unpleasantly warm in summer.

New York has been forced to resort to a rather distant water supply. The Hudson River water cannot be used because the stream is tidal for a hundred miles from its mouth, in contrast to the Thames, which is not tidal above London. The old city of New York, and most of its newer residential sections, lie on ancient crystalline rock, notoriously poor in ground water. Except for a little artesian water in Brooklyn, there is no source of supply comparable to the artesian basin which underlies London. Moreover, New York is divided into four sections by deep straits or bays, a condition which greatly complicates the problem of distribution.

The rugged and sparsely settled hill country bordering the Hudson is capable of furnishing pure water in abundance. As early as 1842 Croton Creek, an east-bank tributary of the Hudson, had been dammed to form a reservoir, from which tunnels and aqueducts 38¼ miles long conducted water to Manhattan Island. This source of supply was increased from time to time, until all the available water on the city side of the Hudson had been drafted. During the first quarter of the nineteenth century the Catskill drainage was pressed into service. Reservoirs impound run-off from both the southern and the northern slopes, and tunnels and aqueducts aggregating 110 miles in length lead to the northern outskirts of the city. Additional bores distribute water to the several boroughs. The major engineering achievements of these works are a tunnel beneath the Catskills, which carries water from the northern slopes to the southern, a tunnel more than a thousand feet beneath the Hudson River, bores under Harlem and East Rivers to serve Manhattan and Long Islands, and a flexible pipe laid on the floor of the harbor from Long Island to Staten Island, the terminal of the system. Several small reservoirs within the city limits equalize the flow into the mains, and hold a small reserve supply. The reservoirs in the hill country are much more capacious; the largest alone maintains a reserve sufficient to supply the city for more than 300 days.

Cities located on large lakes of fresh water have an inexhaustible supply at their very doors. Chicago, the largest of the Great Lakes

cities, may be selected as representative of this group. Lake Michigan has been drawn upon ever since the congestion of population resulted in pollution of shallow wells sunk in the glacial till which underlies the city. Although originally much clearer and purer than river water, that of the lake became contaminated by city sewage, which, following natural drainage lines, poured into the lake. Intakes for the water system, which originally had been along the shore, were built farther and farther out, but they could not be placed beyond the danger of pollution. In 1870 the city diverted its sewage into the Illinois and Michigan Canal, and thence into the Illinois River, *away* from the lake. As the city grew and the amount of sewage increased, this solution of the difficulty became quite inadequate. Every heavy rain caused sewage to flow into the lake, and the typhoid rate of Chicago became very high. The problem finally was solved about 1900 by cutting a large canal through the low divide which parts the waters tributary to Lake Michigan from those tributary to the Mississippi River. This canal reverses the current of the Chicago River, and thus draws water from the lake to dilute the sewage. Sewers which formerly drained directly into the lake have been intercepted by lines parallel to the shore; these lines lead into the river or the Drainage Canal. The intakes for the city water supply are placed from two to four miles out in the lake, beyond the zone of shore waters ordinarily polluted by refuse washed from the land and by bathers. Tunnels under the bottom of the lake carry the water by gravity from the intakes to the pumping stations in the city, which force it into distributing mains. The supply is exhaustless and constant, although in late summer it becomes somewhat warm, and occasional winter gales make it muddy. Very recently the other cities about the Great Lakes have protested at the amount of water Chicago uses for sewage dilution, and it is not unlikely that the city will have to devise some other means of waste disposal than that now employed.

A number of hotels and manufacturing plants in Chicago have artesian wells of their own which tap water-bearing sandstones. Although not flowing wells, water rises to within a few score feet of the surface, and thus minimizes pumping.

Los Angeles may be chosen to represent the group of cities which has grown up in regions of scanty and fluctuating rainfall. Not only is the underground supply small, but perennial streams do not exist, and even the mountains immediately back of the city cannot be relied upon. The nearest copious supply is that of the snow-fed

streams of the High Sierras, miles distant. Control of the water rights of one of these streams, the Owens River, was obtained, and a concrete aqueduct 250 miles long now carries its waters to reservoirs within the city limits. Nearly the whole length of the aqueduct lies in a desert, and the water is siphoned over two mountain ranges. In addition to furnishing the city dwellers with water for the usual domestic requirements, the system permits the constant irrigation necessary to maintain lawns and gardens, and supplies the farmers of many neighboring square miles with water for their crops. The water is free from pollution, although in its passage across the desert it becomes unpalatably warm during most of the year.

San Francisco has had a problem similar to that of Los Angeles, except that the water does not have to be transported quite so far, and the region traversed is less arid.

THE EXTENSION OF IRRIGATION IN THE NILE VALLEY

The history of Egypt is the story of irrigation. The Nile, by virtue of its annual overflow, irrigated a small acreage of its floodplain each year, and thus provided a basis for a few rapidly growing crops, which could mature before the soil dried out. Before the dawn of history the people of Egypt had learned to supplement this natural irrigation by carrying water from the stream by hand. Very early, sweeps, wheels, and other devices were contrived to lessen the labor of hand irrigation, and among the earliest human records is an account of the construction of dikes and canals.

Throughout the period of Egyptian glory the irrigated acreage was enlarged by increasing the amount of water drawn from the Nile, and by extending the canals so as to reach lands well above the stream. With the decline of the state, irrigation works were abandoned, particularly on the delta, and it was not until the latter part of the nineteenth century that the irrigated area was again extended to include most of the arable land of both floodplain and delta. Now the irrigated acreage is larger than ever before, and much of the land can be irrigated throughout the year, a thing which was impossible in ancient times.

Some fifty years ago dams were built across the two major dis-

tributaries of the Nile near the head of the delta. Their construction proved very difficult on account of the unstable foundations, and they could not be used to impound flood waters, but only to divert the normal flow of the stream into canals on the delta. Between 1898 and 1908 other similar dams were built on the delta, and at Assiut and Esna, between the head of the delta and the first cataract. Each of these works considerably raised the level of the river at lowest water, and so supplied water to higher levels than had ever been irrigated, and increased the amount available in the season of low Nile. Neither of them, however, was intended to impound flood waters. That service was the business of the dam at Aswan, at the first cataract, built between 1898 and 1902, and increased in height between 1907 and 1912.

At the first cataract the river tumbles over ledges of hard rock, which form a suitable foundation for a strong dam. The dam is a mile and a quarter long and 130 feet high, the water above the dam being 88 feet higher than the surface of the stream below. Water is ponded 185 miles upstream, the total storage capacity being 9,000,000,000 cubic feet. The silt which accumulates above the dam is washed out at flood season through sluiceways near the bottom of the reservoir. The Aswan Dam makes it possible to grow two or three crops a year, where formerly there was water enough for only one, and it brings a large additional acreage into use.

The total arable area of Egypt amounts to 6,663,000 acres, of which 5,351,000 acres are under cultivation. Of this, 1,287,000 are irrigated only a part of the year, the remaining 4,064,000 acres being under perennial irrigation, for which the modern works described in the preceding paragraphs are responsible.

IRRIGATION IN THE UTAH OASIS

Utah was the first agricultural settlement in the American desert, and it remains one of the very few in which the land has been reclaimed by the co-operation of individuals, practically unassisted by federal capital and federal engineers. These facts suggest that the natural environment is exceptionally favorable to irrigation development.

The "Utah Oasis" consists of a series of piedmont alluvial and lacustrine plains lying along the western base of the Wasatch and

San Pitch Mountains. The gentle slope of these lands is ideal for irrigation canals, the porous alluvium absorbs excess water, which finds its way into the drainage system of Great Salt Lake, and the soil is fine in texture and rich in mineral plant food. The mountains, rising steep and high close to the upper margin of the valley plains, receive a moderately heavy precipitation, and so give rise to streams which flow out on to the arid plains. The maximum precipitation comes in the winter in the form of snow, which melts gradually as spring advances. These waters are brought down to the valleys by numerous *small* streams, so that diversion is easy at several points and widespread distribution of the water with a minimum mileage of canals is possible, although the lack of a comprehensive plan has resulted in needless duplication of canals.

Even though aided by these favoring conditions, the Mormon pioneers, accustomed to farming in humid Illinois and Iowa, were compelled to adopt novel economic and social practices. The first settlement was made at Salt Lake City, where all hands co-operated in diverting the waters of a small creek and in planting grain. This practice was adhered to in the years which followed. When a settlement grew to the point of overtaxing its irrigated land a carefully selected group of people was sent to a neighboring streamlet to divert its water and found a new agricultural community. In this fashion the settlement spread north and south over a zone some 200 miles long within ten years. The next two generations settled upon the intervening arable land passed over by the pioneers, until now the distribution of population is almost identical with irrigable land. Farmers continue to live in villages, from which they go out each day to work their land. The maintenance of dams and canals is a co-operative community enterprise.

Farms are small because the intensive cultivation which irrigation imposes is laborious, and the yield per acre is high because the fertile desert soil is kept provided with exactly the quantity of water required by the crops. The canal-bordered roads divide the fields into rectangular plots, spread over the bed and beaches of the prehistoric lake which once filled the basin in which Great Salt Lake is a shrunken remnant. On the lowest land, particularly that along the shore of Great Salt Lake, the soil is likely to be too heavy or too strongly impregnated with alkaline salts to permit tillage. There herds of cattle graze on the native salt grass. On the higher portions of the lacustrine plain, and on the coarser soils of beaches, bars, and deltas

associated with the ancient lake, are the cropped lands, irrigated, and alternating with almost the regularity of the squares on a checkerboard, so carefully planned is the rotation system. Alfalfa occupies more acreage than any other crop, but sugar beets rank first among cash crops, and fruits from commercial orchards, wheat, and vegetables are important items in the agricultural system. Thickly dotted over the plain stand clumps of Lombardy poplars marking the location of farm villages. Most of the orchards are planted on the higher ground and coarser soils, made up of sands underlain by gravels, which fan out in front of the mouths of the canyons. So located, they benefit from air drainage and from warm soils, which combine to bring on the spring two weeks before it comes to the lower-lying, wetter lacustrine plain. On the lands which lie too high for irrigation (mostly deltas of streams tributary to the ancient lake), winter wheat is raised under dry-farming methods. It is noteworthy that most of these lands are devoid of trees and dwellings, being worked by farmers who own a patch of irrigated land as well, and who live in the farm villages on the irrigated plain. The dry-farming is possible, and the acreage under irrigation is large, compared to the amount of water, because of the winter and spring rainfall. Even in the irrigated sections the farmers depend on the rains until about the first of June, saving the precious irrigation water for midsummer.

TOTAL LAND AREA, IMPROVED LAND IN FARMS, AND IRRIGATED LAND, FOR EACH OF THE STATES OF THE UNITED STATES[1]

	Total Land Area, 1920 (Thousands of Acres)	Improved Land in Farms, 1920 (Thousands of Acres)	Irrigated Land, 1919 (Thousands of Acres)
United States	1,903,215	503,073	19,192
New England:			
Maine	19,133	1,977	.....
New Hampshire	5,780	703	.....
Vermont	5,839	1,692	.....
Massachusetts	5,145	909	.....
Rhode Island	683	133	.....
Connecticut	3,085	701	.....
Middle Atlantic:			
New York	30,499	13,159	.....
New Jersey	4,809	1,556	.....
Pennsylvania	28,692	11,848	.....

Table continued on next page

[1] Compiled from the United States Census, 1920.

TOTAL LAND AREA—*Continued*

	Total Land Area, 1920 (Thousands of Acres)	Improved Land in Farms, 1920 (Thousands of Acres)	Irrigated Land, 1919 (Thousands of Acres)
East North Central:			
Ohio	26,074	18,542	.....
Indiana	23,069	16,680	.....
Illinois	35,868	27,295	.....
Michigan	36,787	12,926	.....
Wisconsin	35,364	12,452	.....
West North Central:			
Minnesota	51,749	21,482	.....
Iowa	35,575	28,607	.....
Missouri	43,985	24,833	.....
North Dakota	44,917	24,563	12
South Dakota	49,196	18,199	101
Nebraska	49,157	23,110	443
Kansas	52,335	30,601	47
South Atlantic:			
Delaware	1,258	653	.....
Maryland	6,362	3,137	.....
District of Columbia	38	4	.....
Virginia	25,768	9,460	.....
West Virginia	15,374	5,520	.....
North Carolina	31,194	8,198	.....
South Carolina	19,517	6,184	.....
Georgia	37,584	13,055	.....
Florida	35,111	2,297	.....
East South Central:			
Kentucky	25,716	13,976	.....
Tennessee	26,680	11,185	.....
Alabama	32,819	9,893	.....
Mississippi	29,672	9,326	.....
West South Central:			
Arkansas	33,616	9,211	144
Louisiana	29,062	5,626	455
Oklahoma	44,425	18,125	3
Texas	167,935	31,228	586
Mountain:			
Montana	93,524	11,007	1,682
Idaho	53,347	4,512	2,489
Wyoming	62,431	2,102	1,208
Colorado	66,341	7,745	3,348
New Mexico	78,402	1,717	538
Arizona	72,838	713	468
Utah	52,598	1,715	1,372
Nevada	70,285	595	561
Pacific:			
Washington	42,775	7,129	530
Oregon	61,188	4,914	986
California	99,617	11,878	4,219

IRRIGATED AND IRRIGABLE LAND IN THE UNITED STATES, 1919 AND 1920, IN ACRES[1]

State	Area Irrigated, 1919	Area Enterprises Were Capable of Irrigating	Area in Enterprises, 1920	Estimated Irrigable Area (Including Irrigated)
California	4,219,040	5,894,466	7,805,207	10,000,000
Colorado	3,348,385	3,855,348	5,220,588	5,000,000
Idaho	2,488,806	3,092,810	3,780,048	5,500,000
Montana	1,681,729	2,753,498	4,329,148	6,000,000
Utah	1,371,651	1,700,550	2,359,244	2,500,000
Wyoming	1,207,982	1,831,039	2,564,668	4,000,000
Oregon	986,162	1,344,046	1,925,987	3,000,000
Texas	586,120	1,150,542	1,687,447	3,000,000
Nevada	561,447	704,708	1,382,036	1,500,000
New Mexico	538,377	696,119	961,879	2,000,000
Washington	529,899	637,151	836,795	3,000,000
Arizona	467,565	627,303	813,153	1,000,000
Louisiana	454,882	728,742	851,211	.....
Nebraska	442,690	562,468	766,768	1,000,000
Arkansas	143,946	179,013	246,480	.....
South Dakota	100,682	150,914	188,382	1,000,000
Kansas	47,312	67,853	102,562	500,000
North Dakota	12,072	34,235	57,476	1,500,000
Oklahoma	2,969	9,672	11,742	500,000
United States	19,191,716	26,020,477	35,890,821	51,000,000

[1] O. E. Baker, "A Graphic Summary of American Agriculture," United States Department of Agriculture, *Yearbook*, 1921, p. 429. Washington, 1922.

THE SALT RIVER VALLEY IRRIGATION PROJECT[1]

"Deficient rainfall has prevented the extensive practice of agriculture in Arizona, and has condemned the state to a sparse population. Less than 1/200 of its area is cultivated, and though the 5th state in size it is 46th in population. If enough water were available, nearly half the state could be farmed; as it is, probably not more than two per cent of the land ever can be irrigated. How much can be 'dry-farmed' successfully is quite uncertain. Little can be farmed by ordinary methods. The Salt River Valley about Phoenix is the leading agricultural section, its irrigated fields making nearly half (43 per cent) of the improved farm lands of the state in 1910. . . . .

"Outside the irrigated tracts, the plain is a desert, the rainfall at Phoenix averaging only 7 or 8 inches a year. The scattered plants of the desert represent types which have unusual ability to get water from the dry soil, or special devices to reduce the loss of water. Since little or nothing can be grown on it, most of the non-irrigable land of the desert plain is nearly worthless. To the east, the mountains and the plateau escarpment compel the passing winds to yield more rain, the amount varying almost directly with the altitude. The average yearly precipitation at Fort Apache (5,050 feet above sea-level) is about 20 inches. Many of the higher slopes are forested, and here, too, many streams rise.

"The Salt River and some of the other streams which flow from the relatively humid uplands have long afforded water for the irrigation of a small part of the desert lowlands. Scattered throughout the Salt River Valley are the remains of ancient irrigation works which show that in prehistoric times more than 100,000 acres were irrigated. Modern irrigation in the valley dates from 1867, when a canal was built to divert a part of the natural flow of the river.

"The volume of Salt River varies greatly, and until provision was made for storing its flood waters the supply of water for irrigation frequently was inadequate. At times the volume of the river did not exceed 100 cubic feet per second, and again it was several hundred times that amount. . . . . Such conditions made irrigation very uncertain. Most of the old diversion dams in the river were temporary affairs built of brush and rock; frequently they were swept away by floods. At such times they could not be repaired until the river had

[1] Harlan H. Barrows, "Roosevelt Dam and the Salt River Valley," *Journal of Geography*, XI (1912–13), pp. 277–284.

again reached a low stage, and then there was little water for irrigation. Encouraged by occasional years of relatively large water supply, the settlers increased the area under irrigation to such an extent that in drier years much farm land could not be watered. There was an insufficient supply of water during much of the decade 1890–1900, and during that period some farm land reverted to desert. Stable conditions and further agricultural development could come only with the construction of storage reservoirs and the utilization of flood waters. . . . .

"The site chosen for the Roosevelt Dam, the principal feature of the Salt River project, is in the narrow canyon of the Salt River, just below its junction with Tonto Creek and about 75 miles northeast of Phoenix.

"[Environmental] conditions made the construction of the dam difficult in many ways. Its successful completion was a notable achievement, for few if any kinds of engineering work require greater care and skill than the building of a large and permanent dam across a river. The site of the dam is in a rugged and nearly uninhabited torrential region, 60 miles from the nearest railroad station to the west (Mesa) from which food stuffs, hay, grain, machinery, etc., were hauled by wagon. To make this possible, a road was constructed with difficulty to the site of the dam. In places in the mountains, cuts 60 to 70 feet deep in the solid rock of nearly vertical cliffs were necessary, and at other points rock-fills 75 or more feet high were required. Some sections of the road cost $25,000 a mile. Large quantities of lumber, brick, and cement were required for the work, but the long wagon haul made the cost of bringing such materials from outside prohibitive. Accordingly the Reclamation Service manufactured these things near the dam. A sawmill was erected in the Sierra Ancha, some 30 miles from the dam, and timber owned by the government was used to manufacture the needed lumber. Clay and limestone occurring near the site of the dam, a Portland cement plant was built, in which some 340,000 barrels of cement were made. The cement was transported from the mill to the site of the work on an aerial tramway a third of a mile long. To obtain a supply of sand, it was necessary to quarry and crush sandstone, for the only natural sand in the vicinity was in the bed of the river, where it was inaccessible during floods. A large amount of power was needed for the auxiliary plants and for the construction of the dam. Wood, the only local fuel, could not be used economically, and the cost of transportation precluded importing

large quantities of coal or oil. Oil which cost 19 cents a barrel at Bakersfield, California, cost $3.48 a barrel at the site of the dam. Accordingly, a hydro-electric system to develop 4,400 horse-power was constructed. Water from Salt River is turned into a power canal by a diversion dam located some 19 miles above the Roosevelt Dam. The power canal, which has less grade than the river, conveys the diverted water to a point near the Roosevelt Dam, from which it descends 220 feet in an inclined penstock tunnel in the walls of the canyon to turbines located in a power house just below the dam. Offices, warehouses, work shops, residences for engineers and other employees, a hospital for the benefit of laborers, and other buildings were constructed, together with lighting, water, and sewer systems for the temporary town which grew up on the floor of the future reservoir as work progressed. Common labor was not easy to get, partly because of the distance from other towns and the regulations (such as the exclusion of saloons) enforced by the government. The problem was solved in part by employing several hundred Indians, descendants of the Apaches who, from their mountain retreats, had warred upon the early settlers of the region. The sandstone for the dam was quarried from the neighboring walls of the canyon, and the first masonry was laid in September, 1906. In spite of many delays during the earlier stages of the work, due to repeated floods in the river, and in spite of the difficulties already referred to, the great dam was completed in February, 1911. The Reclamation Service had furnished some water to irrigators since 1907.

"Roosevelt Dam is 280 feet high, 235 feet long at the bottom, 1,080 feet long on top, and contains 342,000 cubic yards of stone and cement. At each end of the dam there is a spillway 200 feet long and 220 feet above the stream bed. These spillways were excavated from the walls of the canyon, and are spanned by great arches of re-enforced concrete which support roadways connecting with the 16-foot roadway along the top of the dam. The reservoir controlled by the dam has an area of 16,320 acres, and a capacity of 1,284,000 acre-feet. The waters in the reservoir form a beautiful lake, called Lake Roosevelt. Most lakes are being destroyed slowly. Sediment washed into a lake from the tributary slopes displaces an equal volume of water, and if continued long enough, deposition will fill the basin and obliterate the lake. Sedimentation in Lake Roosevelt, though rapid, is reduced by the fact that many of the tributary slopes are timbered and are within the Tonto National Forest, where grazing

is regulated. Both the trees and the partial cover of grass reduce soil wash. It is estimated, however, that the reservoir will be nearly filled with sediment in 200 years. In time, therefore, sediment must be dredged from the lake, or the dam must be built higher. One of the outlet tunnels extends from near the bottom of the reservoir, around the south end of the dam through the walls of the canyon, to the river bed below. The waters issuing through this tunnel carry out some of the silt from the bottom of the reservoir, and so retard the filling of the latter. Another outlet, at the north end of the dam, takes water from a higher level in the reservoir, and conveys it to a 260-foot rock tunnel. The water escapes on the side of the canyon below the dam, forming attractive falls. A third outlet takes water from the reservoir at a point some 65 feet above the bottom, and carries it down to the power house below the dam, where it is utilized for power purposes before being discharged into the river.

"The water taken from the reservoir flows down the channel of the Salt River for 40 or 50 miles before reaching the mouth of the canyon and the edge of the [piedmont plain]. Together with most of the water which is brought to the Salt [River] by its tributaries below the Roosevelt Dam, it is then turned through huge head gates into canal systems on both sides of the river by the Granite Reef Diversion Dam. This structure is 38 feet high and about 1,100 feet long, and is located a few miles below the mouth of the Verde River. More than $10,000,000 have been expended on the storage works, power system, diversion dam, and canal systems.

"The irrigable area in the Salt River Valley is limited by the supply of water, and covers about [213,000 acres. Approximately 205,000 acres were being irrigated in 1919, of which more than 188,000 acres were in crops, the remainder being home sites, town sites, roads, and canals. Eight hundred and fifteen miles of canals were in operation in 1917].

"Agriculture in the Salt River Valley is both intensive and diversified. Winter temperatures being relatively high, irrigation is carried on throughout the year. . . . . Most of the soils of the irrigated area are rich in mineral plant foods; they were formed from the varied rocks of the neighboring uplands, and ground-waters, coming to the surface through capillary action and evaporating into the dry air, have deposited in them the mineral matter dissolved during their journey underground. The high value of the irrigated lands encourages methods of tillage which secure maximum yields from minimum

areas. [Nearly half the cultivated area is in alfalfa, which is cut five or six times a year, more than a quarter is in pasture, and an equal acreage is used in growing grain, chiefly grain sorghum, barley, and wheat. The remainder is devoted to a wide range of products, including Egyptian cotton, semi-tropical fruits, and vegetables, particularly cantaloupes and watermelons.] Delicious dates are grown near Phoenix, and the industry promises to become an important one. Range cattle are fattened on the alfalfa, which also helps to support an important dairy industry. An interesting industry is the raising of ostriches; the birds are turned loose in the alfalfa fields, and are said to be handled in much the same way as cattle. [The crop value per acre over the whole project averages about $50.00.]

"The hydro-electric power developed in connection with the irrigation project will be an important factor in the industrial life of the region, for the latter is far from productive coal fields. A total of 18,000 to 20,000 horsepower can be developed—9,000 at the Roosevelt power plant from the power canal and reservoir, and the rest at points along the river and at drops in the canals. Formerly, the power developed at the Roosevelt Dam would have had little value following the completion of the storage works, for the industries using water power had to be located close to the source of the power, and transportation and other conditions would prevent the establishment of industries at Roosevelt. During recent years, however, there have been rapid developments in the transmission of energy in the form of electricity, and now a water power, if sufficient, can serve an area of 100,000 to 125,000 square miles. About a third of the power developed in connection with the Salt River project will be used to pump groundwater for irrigation, and the rest will be sold to manufacturers, mining companies, farmers, and others. . . . . Electricity generated by the hydro-electric power plant at the reservoir runs street cars, lights buildings, and is used for other purposes in Phoenix, 75 miles away. The sale of this power will in time repay the cost of the irrigation works.

"With the beginning of the Roosevelt Dam, the Salt River Valley entered upon a new era of prosperity. This fact is reflected in various figures recently issued by the Bureau of the Census. Thus, the average value per acre of farm land in Maricopa County, within which most of the irrigated land lies, increased from $30.56 in 1900 to $104.50 in 1910. During the same period the value of all farm property in the county increased from $8,214,002 to $33,879,281, and the popula-

tion from 20,457 to 34,488. The population of Phoenix, the business center of the irrigated district, increased from 5,544 in 1900 to 11,134 in 1910 [and to 29,053 in 1920]. Had the Roosevelt Dam not been built, the admission of Arizona as a state might have been delayed for years. It makes possible one of the garden spots of America, in the midst of a desert."

THE PRACTICE OF IRRIGATION

It is commonly assumed that places receiving less than 10 inches of precipitation in the year are deserts, and that places where 10 to 20 inches fall are semi-arid. This is not strictly true, since the distribution of rainfall through the year, the rapidity of evaporation, and even the character of the soil, affect the availability of rainfall to crops. The following table is an estimate of the percentage of the land surface of the earth receiving specified amounts of rainfall annually:[1]

	Per Cent
Less than 10 inches	25
From 10 to 20 inches	30
From 20 to 40 inches	20
From 40 to 60 inches	11
From 60 to 80 inches	9
From 80 to 120 inches	4
More than 120 inches	1

It is fair to estimate that nearly one-third of the earth's land surface is too dry for crops, unless it can be irrigated.

It is often taken for granted that all deserts can ultimately be irrigated. Nothing is farther from the truth. Estimates for the United States show that not more than one-twelfth of its dry land ever can be watered. In some places there is no suitable site for a reservoir, in others the land to be irrigated is so hilly that canals cannot be constructed, and in most deserts there is a lack of water. The very location of many deserts and semi-arid lands—on the lee side of mountains or extensive land masses, or in the interiors of continents—is an indication of this deficiency of moisture. Moreover, all the dis-

[1] Adapted from John A. Widtsoe, *Dry-Farming*, p. 33. New York: Macmillan, 1911.

tricts at present irrigated, except those which depend upon ground water, are reclaimed by streams which owe their origin to humid climates, either outside the deserts or on highlands within them. The soil of deserts, unless alkaline or of stony shingle, is everywhere fertile; therefore soil is not a deterrent to irrigation, except in a few restricted areas. Indeed, the extraordinary richness and endurance of desert soils has been suggested as a partial explanation for the persistence of advanced civilizations in irrigated countries which have been occupied for thousands of years.

Irrigation is limited chiefly by available water. To render the water available, all manner of devices have been invented. Since most rivers lie below the land to be irrigated, the most primitive irrigation undertook to lift the water on to the fields. Man power has been used for this purpose from time immemorial in Egypt, India, and elsewhere among primitive or dense populations. Various contrivances are used to reduce the labor, most of them designed to counterbalance the receptacles for water with a weight, on the principle of the old-fashioned well-sweep. Animal power likewise has been utilized since remote antiquity, a common application being the Persian wheel, so constructed that a horse or ox walking around a circle turns a water-wheel. Another ancient method forces the stream to do its own lifting by means of a water-wheel equipped with buckets which throw their burden of water into a sluiceway. A modern edition of the water mill is the hydraulic ram. Windmills are used for irrigation as well as for many other purposes. In very recent years gas engines and electric motors have supplanted other devices in the richer countries, notably the United States.

Even the most up-to-date contrivance for lifting water is slow and costly, and wherever possible, irrigation is by gravity. In a few cases, streams have head enough to require nothing more elaborate than a diversion ditch leading to the fields. Generally, however, fluctuating rainfall makes it necessary to dam the stream. A diversion dam raises the level of the water sufficiently to supply the canals, but it cannot create any considerable storage. Therefore in many of the more pretentious irrigation projects a dam is constructed to create a storage reservoir, and flood waters are impounded and held until needed. The Nile irrigation system illustrates both these types of dams, those below the first cataract being used to maintain a head sufficient to divert water into the canals, whereas that at Aswan creates a storage reservoir.

Ordinarily irrigation water is applied to the land through canals having a low gradient. By means of lateral canals the water is led from the main canals to the edge of the fields, where floodgates control its flow over the land. In the case of primitive works, even the main canals are mere ditches. In the better-planned projects, to prevent loss of water and waterlogging of the soil by seepage, it is common to line the larger canals with some impervious material, such as concrete. A further refinement, almost universal in California, converts the canals into covered aqueducts to prevent loss of water through evaporation.

Water is so precious in irrigated regions that great care is taken to make it go as far as possible. The amount of water which will supply a crop with moisture sufficient to mature it is spoken of as the "duty of water." In some of the oases of the Sahara the amount of water required for a single date palm is known to the cupful, and not an excess drop is bestowed upon the trees. Growing a crop under irrigation requires more labor per acre than does production of the same crop without irrigation, but because of the far higher yields, the labor requirement per unit of product is less. It must not be supposed, however, that irrigation makes farming easy. Sound judgment is needed to determine when and in what quantity water shall be applied to a crop. An unexpected and discouraging result of irrigation is the tendency of the ground-water level to rise until the land is "swamped" or "waterlogged." When this occurs many plants die, because their roots are deprived of air; deep-root crops must give way to shallow-root plants, with resultant decrease in crop yield; and alkali is likely to be brought to the surface and deposited by the evaporating moisture. In some cases of water-logging, the phosphate content of the soil is dissolved out, and the humus content is soured, thus permanently injuring the land.

Although irrigation has been practiced unceasingly since prehistoric times, the irrigable area of the earth is by no means fully reclaimed. In the United States, which ranks among the leading countries in desert reclamation, only a little more than one-third of the acreage estimated as irrigable land had been "brought under the ditch" up to 1919. Prohibitive costs of dam and canal construction, lack of a market for crops which can be raised, and laws which prevent the diversion of water are among the reasons for this fact. In most deserts a far smaller percentage of the irrigable land has been reclaimed Presumably new land will be watered as fast as the world's demand for crops warrants, until all reclaimable areas are irrigated.

Among irrigated regions India easily ranks first, with approximately half the total irrigated area of the globe. Some water is drawn from wells, but much more from streams. In 1921, 27,000,000 acres had been irrigated by the British government, leaving out of account the millions under native undertakings. Some 9,800,000 acres are irrigated from the Indus and its tributaries. The distribution of the rivers of the Punjab, resembling the fingers of the hand, has made possible the construction of a system of canals which is economical of water by affording repeated re-use. The upper Ganges system also is used for irrigation. The streams of both Ganges and Indus are fed from the perennial snows of the high Himalayas and the monsoon rains of the lower slopes. On the Deccan there are no large streams heading in snow or rainy mountain ranges, and irrigation depends wholly upon many relatively small reservoirs. In the Deccan section of the province of Madras alone there are some 33,000 "tanks," as the reservoirs are locally called. Many streams are dammed at several places, so as to form a series of reservoirs. Most of these works are of native construction—mud embankments and open ditches—but there are some modern British undertakings.

Second to ancient India in irrigated acreage stands youthful United States. Much of this development has been due to the active support of the federal government. In 1919 the United States Reclamation Service was prepared to supply water on projects of its own undertakings to 1,636,159 acres; 1,187,225 acres actually were irrigated, and 1,113,469 acres were under crops. The average value of the crops per acre was $79.88, ranging from $367.23 on the Okanagon project, where fruit culture predominates, to $26.10 on a part of the Shoshone project, where hay exclusively is grown. The average crop yield is about double that of unirrigated sections of the country. The desert land before reclamation was worth about $10.00 an acre; its average value has been increased $200.00 an acre. As in India, more than one type of climate is involved. The leading position which California occupies among irrigated and irrigable states is due partly to its size and partly to the fact that not only in the desert but also in the section possessing the dry subtropical climate, irrigation is practiced wherever possible, in order to use the bountiful soil for fruits and vegetables, leaving only the unirrigable land for the less profitable winter crops and for olives.

The desirability of irrigation in the dry subtropical climate is further exemplified in the Mediterranean Region, where more than

4,000,000 acres are under the ditch, 3,000,000 being in Italy, 500,000 in Spain, a like acreage in Southern France, and small districts in other lands. Chile, Australia, and South Africa possess small irrigated acreages in the dry subtropical climate, as well as in desert and semi-arid districts.

Since the dawn of history, Egypt has occupied a prominent place among irrigated regions. The Nile River irrigated part of its valley by flooding each year as a result of seasonal rains in the Abyssinian Highland in which some of its tributaries rise. Control works have enormously increased the acreage irrigated and the length of the season of irrigation. The total area irrigated in Egypt amounts to more than 5,000,000 acres.

The extensive, dry interior of Asia, together with extreme South-eastern Europe, has been irrigated wherever water could be had without heavy expense. 1,500,000 acres under Russian control were being irrigated before the World War. Interior China has practiced irrigation for ages.

In China, however, dry-land irrigation merges with rice irrigation in a humid climate. Along all the coasts of South and East Asia rice flooding is a conspicuous feature of the agricultural system. Humid land irrigation in other parts of the world likewise has specialized objectives. The rice lands of Southern United States are irrigated, just as are those of similar climate in China. Market gardens and truck farms, where the land is so valuable that no risk of crop loss through failure of the rainfall may be assumed, have water artificially applied. Meadow irrigation is rather commonly practiced in some parts of Europe, for example in the Alps, the Vosges, and even in the south of England. Water is plentiful, and the hay crop is notably increased by allowing streams to spread their waters over the meadows. In a few places city sewage is run on to meadows, as much for its fertilizing quality as for the moisture. Edinburgh and Milan are among the larger cities following this method of waste disposal. In some places irrigation with turbid water is resorted to in order to cover sandy, infertile soil with finer and richer material, or in order to improve the drainage of fen land by building it up. Enrichment has been attained along the Rhône and the Moselle rivers, and in Belgium and Denmark. The fens of the Humber in England by this means are said to have been raised as much as 15 feet in some places.

POWER FROM NIAGARA FALLS

The power possibilities at Niagara Falls are unsurpassed. The Niagara River is a large stream, discharging about 200,000 cubic feet of water per second. It has a total fall of 327 feet between Lake Erie and Lake Ontario, of which 160 feet occurs in a single drop at the "Falls." The Great Lakes (except Lake Ontario) form a series of reservoirs which maintain a nearly constant flow through the river; the maximum discharge is 222,400 cubic feet per second and the minimum 158,000 cubic feet. Moreover, these lakes act as settling basins, so that the water which flows out of Lake Erie is relatively free from sediment at all seasons. Finally, the power site is located on a plain which has a favorable climate and fertile soil, and which lies in one of the more populous regions of the world, a region highly developed in manufacturing and trade as well as in agriculture. These environmental conditions combine to make easy the production of power and to provide a ready market for all power developed.

The water is utilized by withdrawing it from the stream above the falls, and dropping it through penstocks into turbines located in power-houses below the falls, where it is returned to the stream. The increasing demands for power thus threaten the scenic beauty of the falls, which attract almost a million visitors a year and are the basis for a considerable hotel and transportation business. In an attempt to compromise between these antagonistic interests, a treaty has been drawn up between the governments of the United States and Great Britain, restricting the diversion on the American side to 20,000 cubic feet per second and on the Canadian side to 36,000 cubic feet. The amount now used closely approaches the legal limit.

Most of the plants now in operation develop about 15 horse-power for each cubic foot of water used per second. The turbines which generate the power in these plants are located near the base of the falls, and utilize the force of water which drops upon them from a height of a little more than 150 feet. The most up-to-date plant using Niagara water generates almost exactly twice as much power per cubic foot of water as the older installations. This is accomplished by utilizing the drop of the rapids below the falls as well as the sheer fall itself. This permits utilization of the power from a drop of 305 feet, instead of 150 feet, without diverting any additional water from the falls. Incidentally, this newest plant develops more power from

each penstock and set of turbines than any other on earth—55,000 horse-power.

About three-fourths of the total power generated at Niagara is used in the neighborhood of the Falls, but power is also supplied in quantity as far away as Syracuse, New York, 165 miles distant, and Windsor, Ontario, 240 miles in the opposite direction. The large cities of Buffalo, Rochester, and Toronto, and many smaller places, benefit from the cheap power furnished by Niagara water. Much of this power is used for electric lighting and for running electric cars and trains. The rest is consumed by factories located within the radius of transmission.

WATER-POWER RESOURCES AND INSTALLED CAPACITY OF WATER WHEELS IN THE UNITED STATES, BY CENSUS DIVISIONS[1]

Division	Total Potential Water Power				Installed Capacity of Water Wheels	
	Minimum		Maximum			
	Horse-power	Percentage	Horse-power	Percentage	Horse-power	Percentage
New England	868,000	3.11	1,605,000	2.98	1,381,000	14.94
Middle Atlantic	1,357,000	4.86	2,488,000	4.62	1,735,000	18.77
East North Central	832,000	2.98	1,604,000	2.98	812,000	8.78
West North Central	902,000	3.23	1,956,000	3.63	503,400	5.43
South Atlantic	2,346,000	8.39	4,257,000	7.90	1,381,500	14.89
East South Central	1,087,000	3.89	1,964,000	3.64	504,500	5.45
West South Central	353,000	1.26	822,000	1.52	25,700	.28
Mountain	8,694,000	31.11	16,131,000	29.92	1,006,600	10.98
Pacific	11,504,000	41.17	23,078,000	42.81	1,893,000	20.48
Total	27,943,000	100.00	53,905,000	100.00	9,242,700	100.00

* Maximum horse-power is that obtainable with the flow available for 50% of the time. Minimum horse-power is that obtainable at low water.

[1] United States Geological Survey, *World Atlas of Commercial Geology, Part II. Water Power of the World.* Washington, 1921.

The accompanying map shows the outlines of the divisions listed in the table on the preceding page.

THE WATER POWER OF THE WORLD

The *existence* of water power rests on two environmental elements —surface waters and land forms. The *utilization* of water power depends not only upon its existence, but also upon factors of location—distance from centers of dense and progressive population, situation with reference to raw materials, the existence of competitive sources of power, chiefly coal and petroleum, and the accessibility of the power-plant site.

It is self-evident that the force of a given quantity of running water increases with the height and abruptness of its fall; therefore mountain regions are the principal centers of water power. It is equally apparent that the greater the volume of a stream, the greater its power; hence regions on which much rain falls are likely to possess large power resources. Not so obvious, but equally important, are a number of other propositions. (1) The character of the slope must be considered. In general, abrupt falls furnish the cheapest power sites. Because glaciated streams are especially subject to falls and rapids,

it follows that glaciated areas, whether morainal or ice-scoured, are more favorable for the development of water power than unglaciated regions of equal relief. Again, in regions where hard and soft rock strata are alternately exposed, falls and rapids are likely to be numerous and the power resources considerable. (2) The seasonal distribution of stream volume is quite as significant as the volume itself, for it seldom pays to develop more than the minimum power obtainable at a given site. Moreover, floods are likely to damage the power plant. Thus it appears that streams which flow from lakes or perennial snow fields, or which derive their water from a practically uniform rainfall, most closely approach the ideal. Lakes are characteristic of glaciated land forms; permanent snow fields occur in high altitudes and latitudes; uniform rainfall is a phenomenon of the rainy low latitude and the mild-winter–mild-summer types of climate. A varying stream discharge may be partially or wholly corrected by the construction of reservoirs, but this adds greatly to the cost of the power and creates the hazard of devastating floods, should the dams break. (3) Water flowing through a power house should be free from sediment and other solids. Since streams having a high gradient are likely to carry much sediment, this ideal is most nearly approached where lakes serve as settling basins, or where the stream flows over a resistant bed and therefore is unable to pick up much sediment. A region of ancient crystalline rock, scoured by ice, yields the minimum supply of silt. (4) Ice presents a problem to the producer of water power. It is not always easy to keep blocks of ice out of the raceway, and occasionally the flow of water is reduced or cut off by exceptionally thick ice in winter, or by jams in the spring. Since ice is commonest in the higher latitudes or altitudes, and in the continental climates, it would appear that relatively low latitudes and coastal lowlands generally would suffer least from this handicap.

From the foregoing outline it appears that the maximum potential water power may be looked for in rugged highlands in the rainy low latitudes; in glaciated mountains, particularly those having the mild-winter–mild-summer climate; on rough glaciated plateaus and plains, particularly ice-scoured country, but also on moraines left by the latest ice sheets; and in unglaciated mountains having abundant though perhaps unevenly distributed rainfall.

According to estimates of the United States Geological Survey, Central Africa and Eastern Madagascar together possess about one-third of the world's potential water power. These regions lie in

the rainy low latitude climate; they are rugged plateaus with abrupt escarpments, many of which lie close to the sea, where the stream volume is at the maximum; the level upland is dotted with lakes and marshes. The part of South America having the same type of climate, although even more extensive, promises to yield less than one-fourth as much power, because the large streams (except for the headwaters, which are small in volume) flow over a nearly flat plain, and the short streams of the highlands along the east coast of the continent have small drainage basins and relatively little volume. The potential water power of all regions having the rainy low latitude climate may amount to as much as half the world total.

Mountain regions bordering the remaining low latitude types of climate may be capable of yielding as much as one-twelfth of the world's total power. Nearly all of this potential power lies in the Himalayas, although the high mountains of parts of Middle America and Africa contribute a small share.

Glaciated mountains and hills in the higher middle latitudes rank second among potential water power areas, with approximately one-third of the world total. The greatest possibilities lie in mountains near west coasts, such as the ranges of Pacific Canada and the United States, the Scandinavian hill country, the Alps and the Pyrenees, the Southern Andes, and the highlands of New Zealand and Tasmania. Less richly endowed are uplands on east margins of continents or in interiors. These include the Northern Appalachian hills and mountains, the Carpathians, the Balkans, and the Caucasus.

Glaciated plains probably are capable of producing only about one-twentieth of the world's total water power. This fact emphasizes the dominating importance of slope in determining the existence of power, because in other respects glaciated plains are especially favored.

A yield of about one-twelfth of the world's power is offered by highlands, for the most part unglaciated, which border or lie within the humid subtropical climate.

Nothing is more striking than the discrepancy between the distribution of potential water power and the distribution of developed water power. Only about 3% of the world's potential power is developed at present. Moreover, the principal centers lie in glaciated uplands (about two-thirds of the world's developed power), in glaciated lowlands (about one-fourth of the total), and in the humid subtropical climate (about one-twelfth of the total). The developed power in low latitudes amounts to but one-forty-eighth of the total.

From this analysis it appears that potential power is by no means the only condition essential for utilization.

Unless the power site is accessible to a place where there is a demand for power, it is not feasible to develop it. This is at once an engineering and an economic problem.

Until electricity came into vogue, power had to be used within a few hundred feet of the place of generation. By use of the turbine (an extremely efficient form of water wheel) for production, and electrical current for transmission, three significant amplifications in use of water for power became possible: first, the production of enormous horse power by a single plant (almost 500,000 h.p. will be developed by the new Chippawa-Queenston plant at Niagara Falls); second, the linking of many plants, small and large, into a single power system; and third, the utilization of power sites hitherto useless because of their inaccessibility. Under favorable conditions power can be used as much as 500 miles from its source, although the loss in transit is so great that 250 miles comes nearer the present practical radius of transmission. This progress has made it possible to utilize power formerly locked in the recesses of great mountain masses, but even yet there are power regions which are out of reach, such as the Himalayas and parts of the Rockies.

Not all places within feasible transmission distance of power sites require power. The market depends upon population density and the stage of technology a people has reached. This is inevitable, since hydroelectric power finds its chief uses in running vehicles for overland transportation, in driving the wheels of factories, in lighting streets and buildings, in heating, in smelting minerals, and in numberless electrolytic processes—all activities of progressive and rather densely settled communities. Since the most progressive populations in the world have developed in middle latitudes, and specifically in countries which follow the mode of life devised in Western Europe, the usefulness of water power is most apparent to those populations. Western Europe, English-speaking North America, Japan, Tasmania-New Zealand, and Chile account for practically all the developed horse-power. That is, utilization of water for power is confined to regions of potential power which happen to be accessible to "western" peoples.

Not all progressive peoples favored with water power have utilized their resource. Where coal is abundant, the high initial cost of hydroelectric installation may postpone its use. Germany, Czecho-

Slovakia, the United States from Eastern Pennyslvania to Kansas, and Southern Japan, are examples of this retardation because of their coal. On the other hand, water power has been most used by progressive populations which are without coal. The Alps generally, particularly Switzerland, Italy, and France, the Pyrenees, Scandinavia, New England, the Southern Appalachians, California, and Chile are among the leading water power producing regions of the world.

The cost and even the possibility of developing power vary with the accessibility of the site and the volume and fall of the stream. Even though potential power lies well within the limit of transmission, high cost of building and maintaining roads to reach it, insecure foundation for a dam, uncertain regimen of the stream, or snowbound winters may prohibit its utilization.

Natural falls of great height, with a constant volume of discharge, lie ready to the engineers' hands, requiring little construction of dams and conduits. Such falls are commonest in mountains, and particularly in glaciated uplands, where many streams alternately lose themselves in placid lakes and tumble riotously from higher to lower levels. Therefore, such regions in general offer the cheapest production of power, and where the population is relatively dense and adjacent lowlands are occupied by progressive peoples, power development is farthest advanced. The Alps saw the earliest attempts at hydroelectric development (in 1883), and the region now has numerous and large-scale installations. Switzerland has developed 80% of its available power. Long before the days of electricity the glaciated hill country of New England was dotted with manufacturing plants based on water power, and more lately some large power plants and many small ones have been established on the new basis. In the Scandinavian uplands hydroelectric power is quite generally distributed to farms, where it is used for lighting, pumping water, churning, milking, and other farm tasks. Falls on plains generally are lower than in mountains, and the volume of the streams normally is larger. These facts may require the building of long and heavy dams and lengthy canals, but the active demand for power on populous lowlands generally repays the cost. As a result, the percentage of power now developed on plains is higher than in the case of any type of mountain region. The ice-scoured plains and hill country of Eastern Canada and of Finland are traversed by streams capable of supplying enormous power, and a number of sites in the more populous sections are developed in both areas. The power developed at Niagara Falls exceeds

that of any other single site in the world, and a project is now on foot to develop some 4,500,000 million horse power on the St. Lawrence between Ogdensburg and Montreal. In this stretch of 117 miles there is a drop of about 224 feet.

It is noteworthy that power plants within certain regions are being grouped into "super-power systems." By means of the simple device of feeding the electric power from a number of sites into a common distributing system, fluctuations arising from variations in water, stoppages in the machinery, uneven use of power, and other causes can be minimized. Such a system is in effect in the Southern Appalachians, where the erratic distribution of rainfall from year to year has made it exceptionally helpful. Recently, when a period of drouth in the Carolinas synchronized with somewhat more than normal rainfall in Northern Alabama, the mills of the Carolinas drew upon the surplus Alabama power and so avoided a shut-down. Much the same effect is secured in the Sierra Nevadas of California, where a number of streams are subordinated to the needs of the city of Los Angeles; plans are being made to feed into this same system power from the Colorado River. On the Atlantic seaboard it is proposed to link up the hydroelectric plants between Portland (Maine) and Washington (D.C.) and to unite with them the power produced from coal in that region. In addition to the advantages already pointed out, this scheme would eliminate hauling of coal except from the mines to the power plants, many of which could be located near the mines.

Increasing use of hydroelectric power is much to be desired. The resource is just beginning to be tapped, and the estimated potential power amounts to almost four times the current power demands of the world, including shipping. The feasibility of linking hydro- and carbo-electric power into a single system holds out hopes of an easily regulated flow of power, and a picture of cities free from the sooty atmosphere and greasy surface now the rule. Long distance transmission of power permits its use in favorable localities, including those already devoted to the use of power in quantity. At the same time, the location of great water powers in places now sparsely populated will tend to disseminate manufacturing and redistribute transport. During the World War a considerable manufacturing business was built up in the south of France, in the vicinity of the Pyrenees, a district which formerly had been wholly rural. In so far as this process retards the growth of vast cities with their slums for the poor and their artificial living conditions for everybody, it is much to be desired;

and in so far as it brings the vitalizing spirit of industry to stagnating communities now remote from the world's economic currents, it will further benefit humanity.

FLOODS AND THEIR PREVENTION

For a number of reasons the damage caused by floods exceeds that of more spectacular natural phenomena, such as earthquakes and volcanoes. Floods are not localized, but occur in nearly every part of the world. Moreover, they generally devastate river valleys, which are likely to be densely settled, owing to fertile soil, suitable trade routes either via the stream or alongside in its valley, opportunities for irrigation, or water power sites. Finally, floods recur frequently, in some places oftener than once a year.

The basic cause of floods in streams is exceptionally heavy precipitation. Small streams may rise from placid pool to turbulent torrent in a heavy shower of a few minutes' duration. Large streams generally reach flood stage only with prolonged torrential rains. The complex of conditions which cause destructive inundations can be illustrated by two streams notorious for their floods—the Ohio (United States) and the Tisza (Hungary—Yugo-Slavia).

The Tisza River meanders across a nearly level plain, into which it has cut only a shallow channel. Its headwaters rise in the Carpathian Mountains, which winter buries deep in snow that melts rapidly with the coming of spring. At the same time the flood waters of the Danube, into which the Tisza flows, prevent discharge of, and add to, the Tisza freshet by reversing the current in the lower reaches of the tributary. The floods which result recur perennially, so that there is hardly a town on either bank of the Tisza, and farmhouses in the vicinity are placed on hummocks which rise above the plain. Szeged, the chief settlement along the stream, has been damaged nearly every year, and in 1879 it was destroyed.

The Ohio River flows in a valley of moderate depth and gradient. Its headwaters lie in mountains with heavy winter snows and swift spring thaws. Its northern tributaries flow through a region where the ground freezes to a depth of several feet each winter, but where snows alternate with rains throughout the cold season. When, as

often happens toward spring, a warm rain falls upon a considerable accumulation of snow, the runoff is almost complete, owing to the impermeability of the frozen ground. Under such conditions these tributary streams overflow their banks. Since the course of the Ohio does not deviate much from the trend of average isotherms in the region, it is likely to receive the runoff from melting snows of all its tributaries at about the same time. Its own channel is thus overtaxed by the sudden access of tributary waters along its whole length. Frequently it passes the flood on to the Lower Mississippi, which is compelled to take care of the swollen discharge of the Upper Mississippi and the Missouri as well. The most disastrous Ohio Basin flood of record occurred in March, 1913, when a warm rain melted heavy snows in the northern part of the basin, and torrential rains fell over the lower Ohio itself. Nearly every river town in the state of Ohio was damaged, and Dayton and other cities on the Miami, where the floods were highest, barely escaped annihilation.

Floods generally increase with the development of a region, because in subjecting an area to use, people overthrow the nice balance of Nature. They settle in the way of floods—on floodplains or at canyon mouths; they clear the land of forests; they convert much of it into fields of more or less bare soil; they drain marshes and shallow lakes, both on the uplands and along floodplains. All these "improvements" cut down storage of water and speed up runoff into the streams. Then too, people narrow the channel by reclaiming floodplain land and building bridges, particularly in cities. This diminishes the rate of discharge through the stream, thus augmenting the danger from excessive runoff. Most streams are dammed in places, to furnish a head for water power or a reservoir for city water supply or irrigation works. Some of the most disastrous floods have been caused by the breaking of these dams. The inundations of Johnstown, Pennsylvania, in 1887, and of Pueblo, Colorado, in 1921, are examples of this type of flood.

Many schemes for preventing the recurrence of floods have been tried out. The most successful are (*a*) straightening the channel, to increase the gradient and consequently the rate of discharge, and (*b*) building storage reservoirs. The latter recourse is impracticable in many valleys, where the value of the land for farms or the large number of settlements flooded renders the cost prohibitive. In other valleys there are no suitable sites for reservoirs. In fact a satisfactory reservoir site is rather uncommon. The requirements are a capacious

basin, with a marked constriction for a dam site at its lower end, and a suitable foundation for a dam at this narrows.

The Tisza is an example of a stream without suitable reservoir sites. There flood prevention has taken the form of eliminating meanders and building dikes to keep the river in its new channel. Channel improvement has also been adopted for many other streams where reservoirs are unnecessary or overcostly: e.g., the Scioto, a tributary of the Ohio.

Dams and storage reservoirs have been constructed in Western Europe for at least two centuries, especially in Germany and France, where the streams are peculiarly subject to floods. In the United States six reservoirs were built in the upper basin of the Mississippi during the decades following 1880. The most comprehensive scheme of flood water storage ever attempted in this country was undertaken by the city of Dayton, Ohio, after the disastrous flood of 1913. A commission, acting under special authorization from the state, made a careful survey of conditions in the valleys of the Miami River and certain of its tributaries. Property included within the proposed reservoirs was then acquired, railroads and roads were relocated, and five retarding basins were constructed by throwing reinforced earthen dams across the valleys. These are pierced by large conduits at their base which permit free passage not only for all water at normal stages, but also for all except the most exceptional floods. Thus the fertile land of the reservoir bottoms is inundated only in occasional years. Even in years of big floods the passage of excess water is retarded only until there is room for it in the stream channels. At Dayton and other cities, where the danger of and damage from flood is greatest, channels have been deepened and widened, bends modified, bridges elevated, and levees thrown up.

In some regions floods are intensified by jams of flotsam or ice which wedge into narrows or against bridges to form temporary dams. Streams in the higher latitudes which flow in a northerly direction are particularly subject to ice-jams, because the ice in the upper waters breaks up some days or weeks before winter has released that in the lower stream. The St. Lawrence and Mackenzie rivers in North America, and the several rivers of extreme Northern Europe and Asia are noted for their ice blockades. No effectual prevention for these floods has been devised, but they are chronic only in regions of sparse population. At Montreal a special type of wharf has been devised to cope with ice jams and resulting floods.

STRATEGIC RIVER LOCATIONS

Most large inland cities are river towns, because until the advent of railroads the bulk of inland traffic and travel was carried by rivers. Even the railroads did not diminish the business of the larger places, because, first conceived as supplements to river trade routes, the early lines were built to connect river towns with each other and with points off the streams.

Since river towns have depended primarily on commerce for their growth, the larger ones are located along navigable streams at points which have offered special advantages for carrying on trade. Wherever goods must be distributed there is work for merchants, clerks, teamsters, and laborers, and it is these occupations which form the nucleus for any village. But where goods and people in transit are compelled to change their mode of conveyance, the scope of these pursuits is enormously expanded, and a commercial city of more or less importance results. Even through freight must there be unloaded and reloaded, and this necessitates more or less warehousing. Moreover, it pays to make such a bulk-breaking point the distribution center for all places within a considerable radius. Thus not only retailing to the immediate neighborhood, but also wholesaling to a larger region, becomes a part of the city's business. Travelers, compelled to break their journey, may require lodging places. Thus a considerable population finds occupation, and themselves furnish a livelihood for purveyors of food, clothing, shelter, and amusements.

Perhaps the most obvious bulk-breaking point in river traffic is the head of navigation, where goods and people must shift from water to land transport. Such a point may be marked by a waterfall or by rapids as is the case just above St. Paul on the Mississippi, or it may be where gradual shallowing of the stream does not permit boats in common use to go farther up stream.

On most streams some point near the mouth is the head of navigation for the deep-draft vessels which sail the ocean, and there goods must be trans-shipped to river craft. New Orleans, a hundred miles up the Mississippi, illustrates this type of strategic river location. Occasionally, however, ocean vessels go above New Orleans to Baton Rouge. A number of other world-famous cities are parallels to New Orleans—Antwerp, Rotterdam, Hamburg, London, Calcutta, Shanghai, Rosario, and Portland (Oregon), to mention a few.

Where the volume and channel depth of a river is increased by a large tributary it may pay to operate larger vessels on the lower

stream than can float on the shallower upper stream. If so, a confluence city springs up. St. Louis is a capital example of a city which developed in such a location, and Mannheim, Hankow, and Pittsburgh are others.

A falls or rapids in a stream may break it into two navigable sections between which water transport is impossible all or part of the year. At such points a city grows up to care for the movement of goods and people around the obstruction. Louisville on the Ohio is an example drawn from the Mississippi System, and Ichang on the Yangtze, Aswan on the Nile, and Matadi and Stanleyville on the Congo, are other cases in point.

Although not based on necessity for breaking bulk or transferring passengers, many cities of importance have grown up on the outsides of great bends (not to be confused with river meanders), because their location is especially valuable for trade with the surrounding country. A large segment of a circle described about such a bend is closer to the river at that point than at any other, and the trade of the whole area focuses upon the bend. Cincinnati and Kansas City are representatives of this type of city, as are also Galatz, Rumania, Kazan and Samara, Russia, Hankow, China, Timbuctu, French West Africa, and Rosario, Argentina.

The exact site of a city, the general location of which is determined by the considerations outlined in the foregoing paragraphs, is determined by local topography, such as the existence of a terrace, a convenient ferriage, a navigable tributary stream, or by some historical accident, such as the wording of a charter or an agreement with the aborigines.

THE ERIE CANAL AND THE NEW YORK STATE BARGE CANAL

The Erie Canal was among the agencies of first importance in the upbuilding of the Middle West. Over its waters the settlers and their household goods were hauled in small canal boats by plodding mules, and its barges bore the rapidly increasing freight which the "New West" exchanged with the Atlantic Seaboard.

Other canals between the East and the West were projected,

but none was so favorably situated as the Erie. This canal connected Buffalo with Albany, that is, it linked deep-water navigation on the Hudson River with deep-water navigation on the Great Lakes; the others merely linked seaboard streams with the rivers of the Mississippi System. The Erie Canal followed the lowest pass through the mountains, the trough of the Mohawk River, and nowhere rose 500 feet above the sea; the other canals had to follow smaller stream valleys and more elevated passes. The Erie Canal was an all-water route; the others were interrupted on some of the stream divides by inclined planes over which the boats were dragged. Finally, the Erie route was reinforced by numerous branch canals which brought to it the traffic of the Finger Lakes, Lake Champlain, and Lake Ontario; the other canals had few laterals, and none of importance.

Traffic on the Erie Canal was so heavy from the outset that an enlargement was undertaken almost at once. Slowly, however, the railroads began to cut into its business, and almost before the enlargement was completed most of the branch canals had been abandoned, and freight over the main line was small, as compared with that carried by rail. In later years a second enlargement was undertaken, largely to fight railroad monopoly, but this effort was never even completed.

The continued growth of traffic between East and West reawakened interest in canal building throughout the eastern half of the country in the early years of the twentieth century. This bore fruit in a new Erie Canal, forming a part of a New York State Barge Canal System which links Lake Erie, Ontario, and Champlain, and the Hudson River into a single waterway, navigable for large motor-propelled barges. Engineering progress made it possbile to utilize streams and lakes for a part of this water highway, so that 72% of the whole system follows canalized rivers or lakes.

Because of the large volume of traffic on the Great Lakes, and the importance of New York City as a metropolis and port, it was supposed that a canal of the modern type would be much used. Among conditions supporting this expectation are the location between lake and sea, the low level route, the vast trade between the two regions connected, the low cost of water transport, at least where waterway construction and upkeep are borne by the state, and the fact that three-fourths of the people of New York State (7% of the population of the United States) live within two miles of the waterway system. These expectations have not been fulfilled. Traffic is disappointingly small. Out of a capacity of 20,000,000 tons freight a season, the canal carried only 1,485,000 tons in 1922.

The following table furnishes comparative data for the original Erie Canal and its successors.

	Years of Construction	Length in Miles	Depth in Feet	Width at Bottom in Feet	Width at Surface in Feet	Number of Locks	Dimensions of Locks in Feet	Total Lift in Feet	Power for Moving Barges
Original canal..	1817–25	363	4	28	45	84	90×15	689	Animal
First enlargement.....	1836–62	350.5	7	52.5	70	72	110×18	654.8	Animal
Second enlargement.....	1884–98	350.5	9	52.5	70	?	?	654.8	Animal
Present canal..	1903–16	340.7	12	75	123–171	35	340=×44.4	674	Motor

THE ILLINOIS AND MICHIGAN CANAL[1]

"A new and powerful factor in the economic life of the Illinois Valley appeared in 1848 in the form of the Illinois and Michigan Canal. . . . . The canal opened new markets, brought the valley into closer relations with Chicago and the Great Lakes, and modified its life in important ways. The people of the middle valley had before faced for the most part toward the west; from now on they found their closest relations in the east. . . . .

"A canal between Lake Michigan and the Illinois River was first suggested by Joliet, a member of the first white party (1673) that passed along the Chicago Outlet. Albert Gallatin declared in 1808 that there was no doubt of the practicability of opening a canal along this line. Such a canal was considered a probability by a writer in Niles' Register in 1814, who predicted that it would make Illinois 'the seat of an immense commerce.' It was agitated for two decades in Illinois before work was finally begun in 1836 with the aid of large land grants from the government. . . . .

"The canal is nearly one hundred miles long, with its western end at La Salle, the head of navigation upon the Illinois river.

"The first boat to pass through the entire length of the canal from La Salle arrived at Chicago on April 23, 1848, with sugar from New Orleans. The date (May 24, 1848) of the arrival of the first canal boat from Lake Michigan was "a day of rejoicing and triumph" in Peoria. . . . .

[1] Harlan H. Barrows, "Geography of the Middle Illinois Valley," *Illinois State Geological Survey, Bulletin No. 15*, pp. 92–102, 108–109. Urbana, 1910.

"Lumber was the most important article brought into the Illinois Valley through the canal . . . . one of the greatest needs of the prairies. Their occupation led to the exploitation, beginning early in the thirties, of the great forests of Michigan and Wisconsin. Logs cut in the interior were floated down all the streams of Michigan which flow toward the west. At the mouths of these rivers busy towns developed where the logs were manufactured into lumber. . . . . The manufactured lumber was transported across Lake Michigan at low rates to Illinois. . . . .

"Upon the opening of the canal great quantities of pine and cedar lumber were taken into the Illinois Valley. The cost of lumber was immediately reduced one-half at Peoria, and further reductions soon followed. . . . . The lumber business was for years the most important enterprise of Chicago. It was said that the receipts of 1856 required the services of a fleet equal to 166 first class brigs. Chicago lumber merchants established yards at Peoria, Pekin, and other river towns, and delivered lumber by canal boats as far west as Lexington, Missouri, and Ft. Leavenworth, Kansas. . . . .

"Although a great number of different articles were brought from the East by canal to the Middle Illinois Valley, only agricultural implements, machinery, general merchandise, and salt, in addition to lumber, were of any great importance. . . . .

"East bound traffic through the canal was of two general classes, (1) southern commodities seeking a northern and eastern market, and (2) surplus products from the lands bordering the canal and the nearer western rivers to which it led. The Illinois River and Canal became at once an important trade route between the lower Mississippi and the Great Lakes and East, through which large quantities of sugar, molasses, hemp, and tobacco were shipped. The prices of these articles were doubtless much lower than formerly along the Illinois River. In the second class of commodities, corn, pork, bacon, hams, and lard led. Whiskey from the Peoria distilleries was also an important item. . . . .

"The canal made travel to the Illinois Valley less expensive and more agreeable. The trip between Chicago and Peru was four hours shorter than it had been by stage, and the fare upon the best boats was only four dollars, including meals and berth. A slower line of freight and emigrant packets charged two to three dollars. Three packets started daily from each end of the canal in 1849, during which year the travel was equivalent to 26,446 passengers carried its entire

length. At Peru the traveller could secure steamboat transportation to St. Louis for from three to five dollars. . . . .

"The opening of the Illinois and Michigan Canal precipitated a struggle between Chicago and St. Louis for the trade of the Illinois Valley and the West. It was generally anticipated that the great bulk of the produce of the valley would move eastward, and that Chicago would become the great depot for the Illinois River. St. Louis was accordingly opposed to the canal project, and even the merchants of New Orleans were alarmed. . . . .

"In general the results that had been anticipated were realized, and the trade of the Illinois River was reversed, Chicago becoming its great market. The leading commercial journal of the West noted in 1852 that 'as a grain market, St. Louis is becoming less and less important.' That year Chicago received nearly four times as much corn as St. Louis, practically all of it by the canal.

"It is not to be understood that the diversion of trade under discussion was brought about entirely by the Illinois and Michigan Canal, nor that it was confined to Illinois. The canal began it, so far as Middle Illinois was concerned, but it was continued on a vaster scale by the railroads that, in the fifties, were built west from Chicago. A similar change was in progress in adjacent states. The Wabash and Erie Canal reversed the trade of the Wabash Valley, and relieved Indiana of all economic dependence on the southwest. The shipments to the north on the Ohio canals were greatly in excess of those to the south. New Orleans was described in 1850 as a city which 'once the emporium and mart of the immense empire of the west, sees her commercial rank and position fading away.' Ten years later the receipts of grain at Chicago were nearly ten times those at New Orleans. . . . .

"By making it the gateway of the Illinois Valley, the Illinois and Michigan Canal became a powerful factor in the growth of Chicago. The imports of the city increased from about two and one-half millions in 1847 to over eight and one-quarter millions in 1848, the first year of the canal. The exports increased from a little over two and a quarter to nearly ten and three-quarters millions in the same time. The canal helped Chicago to become, in the early fifties, the largest grain and lumber market in the world. The population of the city rose from 16,859 in 1847 to 60,652 in 1853. . . . .

"The year 1855 has been taken as marking the close of the period of steamboat supremacy in the trade of the Illinois Valley. The following years witnessed an extraordinary decline in river trade.

By 1870 only four steamboats, a pitiful remnant of the great fleet of the late forties, ran regularly between St. Louis and Peoria, and but one of these four extended its trips to LaSalle. Seven per cent only of the units of freight received at Peoria in 1875 came by the river. Four years later Peoria received about forty thousand tons of freight by river; this was but a little over five per cent of the total amount received. The next year (1880) only two steamboats made regular trips between Peoria and St. Louis. A writer of the eighties thought it unlikely that water transportation would again be a necessity for years to come.

"A similar decrease occurred in the trade of the Illinois and Michigan Canal. It was described within nine years of its completion (1857) as an 'old fogy institution.' The tolls increased, however, with much variation from year to year, until the middle sixties, and its tonnage until the early eighties; . . . . after that its business rapidly diminished and has now . . . . ceased.

"This decline in water traffic was brought about primarily by the competition of the railroads and the shallowness, during many summers, of the Illinois River. Various other factors contributed to the triumph of the railroad, however, especially (1) the short season open to navigation; (2) the slowness of water transportation; (3) the lack of co-operation between river and canal service; (4) the limited capacity of the canal; (5) the losses involved in steamboat navigation; and finally (6) unreasonable wharfage charges, and over-competition in river trade. (1) The upper Mississippi and its tributaries were closed by ice four months or more each year. The canal was open on the average only 237 days each year between 1848 and 1900. This suspension of traffic was of course very disadvantageous; the railroads were able from the outset to monopolize business for a considerable fraction of the year. (2) The best steamboats on the Illinois River required twenty to thirty hours for the trip from Peru to St. Louis. The canal boats depended upon animal towage which meant slow, tedious travel, and usually involved delays in the harbor at Chicago and at LaSalle, while waiting for steam vessels to tow them. The canal accordingly lost its entire passenger business when the Chicago, Rock Island, & Pacific Railroad opened parallel to it in 1853. The preceding year travel on the canal had been equivalent to 25,966 passengers through its entire length. The Middle Illinois River also lost much of its passenger trade following the opening of the railroad from Peoria to Bureau in 1854. Furthermore, the superior

speed of the railroad secured it the transportation of all perishable and highly manufactured articles. The waterway could hope to compete only in the movement of heavy, bulky, and non-perishable commodities. (3) Through business on the waterway was inhibited for the want of a line of steamboats on the river running in connection with the packets on the canal. Boats plying between St. Louis and Peru had no regular days of starting. The need of remedying this defect was promptly pointed out, but a number of years appear to have elapsed before it was accomplished. (4) The canal could not accommodate boats of more than four feet eight inches draft, carrying a maximum load of about one hundred fifty tons. Even this was not possible when the water supply was deficient. (5) Losses were heavy in steamboat navigation from boilers bursting, machinery breaking, and from other causes. Boats were destroyed not infrequently, and the usual insurance rate on steamboats was from ten to twelve per cent per annum. (6) The facility with which boats could be built was said to have led to over-competition in the river trade, and wharfage extortions and discriminations were complained of at times. It is difficult to judge of the importance of these charges. . . . .

"The importance of the Illinois River and the canal did not end with the loss of their carrying trade. Indeed, their greatest service to date has perhaps been their influence in securing low railroad freight rates. The competing railroads are forced during the season of navigation to establish rates near enough to the water rates so that shippers will prefer land transportation. This has saved the people living along the line of the river and canal many millions of dollars. The value of the canal and river as freight regulators may best be shown by a few specific illustrations from various years:

1. Corn was shipped by water in 1870 from Henry to Chicago, 130 miles, for 5 cents per bushel, wheat at 6 cents. The rate on the Chicago, Rock Island, & Pacific Railroad during navigation was 7 16/100 cents per bushel for corn and 10 cents for wheat; during the winter season the rate was 9 96/100 cents for corn and 12 40/100 cents for wheat. On the railroads not subject to water competition the rates were from 11 to 14½ cents per bushel for corn, and 15 to 18 cents for wheat for the same distance.

2. The competing railroads establish notably lower rates during the navigation season than in winter, when they are in the position of a monopoly. Thus in January, 1875, the railroad rate on flour from

Peoria to New York was 90 cents a barrel. It fell by stages to 50 cents in August, but rose again to $1.00 in the following December. The corresponding variations in the rates on grain, meats, etc., were of similar magnitude.

3. The Chicago, Rock Island & Pacific Railroad has charged 15 cents per hundred pounds for freight from Tiskilwa (a few miles west of Bureau and beyond the reach of water competition) to Chicago, 122 miles, when it charged only 8 cents from Henry to Chicago, 130 miles.

4. In 1901, the railroad freight rates to Chicago in Northern Illinois were lowest along the Illinois River and the canal, and higher with increasing distance from the waterway regardless of the distance from Chicago. Yet in this year the canal itself had virtually ceased to carry freight."

RIVER AND CANAL NAVIGATION IN EUROPE AND THE UNITED STATES[1]

"The construction of canals on level ground had been common since the days of the Egyptians and Babylonians, but it was not until the invention of the chamber lock that it was possible for canals to overcome elevations. This discovery of this simple device led to the rapid spread of canal building throughout Europe. The movement first became prominent in France. The Canal de Briare, connecting the Seine with the Loire, was begun in 1605 and completed in 1642. The famous Languedoc Canal, now known as the Canal du Midi, connecting the Bay of Biscay with the Mediterranean, was begun in 1666 and finished in 1681. This was one of the greatest achievements during the reign of Louis XIV. It was 148 miles in length, and accommodated barges of 100 tons capacity. An elevation of 600 feet was overcome by means of numerous locks, and a further elevation was avoided by a tunnel 700 feet in length. This canal was constructed by private enterprise under a grant from the Government,

[1] Adapted from E. O. Merchant, "A Comparison of American and European Waterways with Special Reference to the Factors Influencing the Development of Water Transportation," *Senate Document No. 469, Final Report of the National Waterways Commission*, pp. 475–501. Washington, 1912.

as were almost all the canals in the early period. During the eighteenth century the French canal system was perfected. Less than 200 miles of new canals have been added since 1800.

"Canal building began early in Holland, where the use of the lock was known even before it was employed in France. Many of the canals were originally constructed for drainage purposes, and later, as the country developed, were also used for transportation. Practically the whole system was completed by the opening of the nineteenth century. Most of the Belgian and many of the German canals were also constructed before the year 1800.

"The period of active canal building in England commenced with the opening of the Bridgewater Canal from Worsley to Manchester, July, 1761. The success of this enterprise furnished the impetus for further construction. In many cases it was less expensive to build canals along the banks of streams than to improve the streams themselves. Particularly was this the case in England, where the principal use of rivers seems to have been to supply water for the canals. When Brindley, the pioneer in canal building, was before a committee of the House of Commons, a member asked him for what purpose he apprehended rivers were created. He replied, 'To feed navigable canals.' About 1790 a mania for canal building developed. Within four years acts were passed providing for the construction of 81 different canal projects, and by the year 1800 practically the whole canal system, aggregating more than 1,000 miles, was completed. A few additions were made between the years 1800 and 1830, but since the latter date there has been no important construction, except the Manchester Ship Canal.

"Canal building in the United States began soon after the close of the Revolutionary War. The period of most rapid construction commenced about 1825, with the completion of the Erie Canal. The success of this enterprise aroused great enthusiasm for canal building. Hundreds of miles of tributary canals were planned by the State of New York, Pennsylvania commenced a rival system intended to link Philadelphia with Pittsburgh and the west, and the Chesapeake and Ohio Canal was begun. The Great Lakes were joined to the Mississippi River System by means of canals between Lake Erie and the Ohio River, and later by the Illinois River-Lake Michigan waterway. All the canals of this period were shallow, and interrupted by numerous locks. In a few cases, the boats were hauled over watersheds by means of inclined planes. In the short distance traversed

by the canal between Newark, N.J. and the Delaware River there were twelve such inclines.

"European canals of this period were similarly shallow and of small carrying capacity. Traffic was slow, owing to flights of locks, inclined planes where the water supply was insufficient for lockage, and tunnels, some of which were three or more miles in length.

"In spite of these impediments, however, many of the canals were extremely profitable. The Bridgewater Canal in England, which cost less than a million dollars to construct, for some years yielded an annual revenue of nearly $400,000.00. The Erie Canal returned in tolls 42½ million dollars on a total public expenditure of 49½ millions. But the introduction of railways set up competition which brought to a close the heyday of canals.

"The period of railway building commenced about 1830. In Europe within 10 years competition between the railways and waterways became severe. This continued for the next 30 or 40 years, at the end of which time the waterways were generally left in a decadent condition. The first railroads often intersected the waterways and served as feeders. As soon, however, as parallel lines were built active competition began. The passenger traffic was the first to pass to the railways. In fact, many of the first railways were intended primarily for the purpose of transporting passengers, and their facilities for carrying freight were very limited. Following the loss of passenger traffic, the higher grade freight business, in which speed was an essential factor, was next to pass to the railways, and finally when the railways had amalgamated sufficiently to form through routes and to offer cheaper rates, they also secured most of the coarse, bulky traffic carried by the waterways.

"In Germany the smaller streams and canals were the first to suffer a marked decline of traffic. The railways were not so successful in direct competition against the Rhine and Elbe, although the normal increase of traffic on these rivers was checked and for some years they barely held their own.

"In France as early as 1844 the superior advantages of the railways had attracted attention and proposals were made to substitute railways for the canals. From 1852 to 1858 the short, disconnected railway lines rapidly amalgamated to form the six large companies which now exist. The severe competition which resulted was most disastrous to the waterways, which did not effect a similar transforma-

tion. The Seine from Paris to Rouen lost three-fourths of its traffic; the Canal Bourgogne from Paris to Lyon lost one-half.

"In England the railways and canal companies began active competition about 1840. When the shareholders of the latter saw their profits dwindle, they became alarmed, and in various ways sought to compel the railways to buy them out. Parliament yielded to the popular clamor, and before the end of the year 1845 one-third of the total canal mileage fell into the hands of the railway companies. Some of the canals thus acquired were used for the roadbeds of new railway lines or abandoned. Others were used for feeders. On almost all the traffic declined rapidly as the result of railway control or competition.

"In the United States railway competition began in 1842, but did not exhibit its full force until the Civil War period. In general private canals were ultimately leased or sold to railway companies, and even the state canals of Pennsylvania passed under railway control. New York and Ohio retained their canals, but nearly all fell gradually into complete disuse. In 1912 New York constructed a new and larger waterway to replace the Erie Canal. The Ohio canals have no modern successors; many reaches of them have been sold for truck farms or building lots, and some sections have been filled up and converted to new public uses—parks, markets, and the like. Since 1837 some 2,244 miles of canal have been abandoned in the United States, representing an original investment of more than 80 million dollars.

"Renewed interest in the development of water transportation began in France during the sixties and in Germany during the seventies. In England, also, investigations were made about the same time and legislation passed to protect the waterways against railway competition. This renewed interest was due principally to a growing hostility toward the railways, which was engendered by discriminations, high rates, and lack of adequate service. In France in 1861 a congestion of traffic took place, which the railways were unable to handle, and great losses resulted to shippers. Furthermore, the railways insisted that they could not make any further reductions in their rates. The high charges which they exacted wherever they enjoyed a monopoly caused much dissatisfaction and the people began to turn their attention to the possibility of relief which their neglected waterways might afford.

"Where the revival of water transportation is in progress the shallow-draft canals are being replaced by modern canals of standard dimensions. The old methods of towage by mule or by man power are now being superseded by towing steamers or electric tractors. Terminals are being built and equipped with the latest appliances. Better types of boats and barges are being used. The tendency also is to make use of rivers whenever their improvement is practicable rather than to construct lateral canals.

"The striking feature of this movement for the revival of water transportation in Germany, France, and Belgium was the nationalization of the waterways and large expenditures by the central Government upon their improvement and maintenance. Nearly all canals not owned by the national Government are the property of lesser political units, such as cities and provinces.

"Holland has never nationalized her waterways to the extent that France, Germany, and Belgium have, the reason being they have never encountered as severe railway competition nor experienced a similar decline in traffic. The waterways exceed the railways in mileage and, it is stated, carry 90 per cent of the total freight traffic.

"England is the only one of the more advanced European countries in which inland water transportation is still in a backward condition. The canals were originally built by private interests and have remained under private control ever since. Thus long-distance travel on the waterways is a practical impossibility.

"In the United States most of the canals in the eastern part of the country are owned or controlled by the railways, while all the navigable rivers have always been under the jurisdiction of the United States. The Federal Government, however, has not undertaken to nationalize State and private canals, as has been done in France. In this country we have a very striking contrast presented—the remarkable growth of water transportation on the Great Lakes and the decadent condition of commerce on many of the rivers and canals.

"Such statistics as are obtainable for the rivers in the United States indicate that few streams during the last two decades have shown any great increase in traffic, while many have shown a decided decline. The rivers showing the largest increase are those estuaries or arms of the sea which furnish ship channels, or harbors for the important seaports on the Atlantic, Gulf, or Pacific coasts. Most of these rivers have a depth of 20 feet or more. There are also a number of other streams of less depth emptying into the Atlantic Ocean,

which, because of their proximity to large cities, have had a steadily increasing traffic. These are located principally along the New York, New Jersey, Delaware, and Maryland coast.

"If we turn to the Mississippi River System and other streams in the interior of the country, we find only a few instances of a large as well as increasing traffic, and these are confined almost entirely to the Ohio and some of its tributaries, especially the Monongahela. The greatest decline in traffic has occurred on the Mississippi River and some of its tributaries. The Mississippi was formerly a great highway of commerce from the interior of the country to the Gulf port of New Orleans, but except for some local traffic has now been practically abandoned as an agency of transportation.

"Whether the inland waterways of this country will ever be used to the same extent as the waterways of Europe is a question often discussed. Those who have been engaged in river transportation and have seen their business dwindle are naturally somewhat pessimistic about its future. The opinion is often expressed here, as it was formerly abroad, that inland water transportation is obsolete, that the railways offer a cheaper and more convenient means of transportation. On the other hand, the vast majority of the people believe that the waterways can afford cheaper transportation and that as the country develops it will become increasingly necessary to utilize them to supplement the railways, whose capacity for handling traffic is not capable of unlimited expansion.

"The rôle played by favorable natural conditions in those European countries where the growth of water-borne traffic has been greatest has seldom been sufficiently emphasized. The view is sometimes held that almost every stream of any size, if improved, or any canal, if constructed, will convey a large traffic. The fact is that the growth of inland water transportation has been greatest in those countries which possess the best river systems combined with the most favorable natural conditions. It is also a noteworthy fact that in most countries the greater part of the inland waterway traffic is carried on a few large streams or canals possessing special advantages. In Germany, where water transportation has shown the greatest increase, 80 per cent of the inland waterway system, aggregating about 6,200 miles, is composed of rivers either free or canalized. Furthermore, it is an interesting fact that the five principal rivers—the Rhine, Weser, Elbe, Oder, and Vistula—flow in nearly parallel lines from southeast to northwest, forming water routes from the

interior of Germany to the North Atlantic or Baltic seaports. Approximately four-fifths of the total water-borne commerce in Germany is carried on the first four of these river systems, only a small section of the Vistula, about 150 miles in length, being in Germany. The Rhine system carries nearly half of the total tonnage.

"The Rhine is by far the most important river in Germany and carries a greater commerce than any other inland waterway in Europe. From the earliest times it has been an important route for commerce and trade to the interior of Europe. The Rhine is not a deep river, but its flow is relatively more uniform than that of most streams. This is due to the fact that the late melting of snow on the Alps maintains the stream flow during the dry seasons and also to the fact that the headwaters of the Rhine drain several lakes in Switzerland, the largest of which is Lake Constance. These lakes act as natural reservoirs to equalize the flow of the stream. Navigation is rarely ever impeded by low-water conditions and is usually possible for 300 days in a year. The direction of the Rhine's flow is very favorable to the development of large traffic, inasmuch as it affords a water route from the most densely populated and industrially developed section of Germany to the great seaports of Belgium and Holland, notably Amsterdam, Rotterdam, and Antwerp. The gradient of the Rhine is, on the whole, very favorable for navigation. At Basle, where it crosses the German frontier from Switzerland, it is about 800 feet above sea level. The current is somewhat swift as far as Strassburg, a distance of 80 miles, when it becomes more gentle. From this point to Emmerich, on the Dutch frontier, there are only two places where the current is rapid. One is at St. Goar and the other at Bingen. The difficulty of getting upstream on these sections of the river has been obviated to a considerable extent by the use of powerful towing steamers.

"The Weser has very few of the natural advantages possessed by the Rhine. The average depth is from 3 to 5 feet, and the flow of the stream is much more irregular. In dry seasons navigation is frequently suspended because of low water. The gradient of the river is also much steeper than that of the Rhine. The principal advantage of the river is that possessed by the other German rivers, namely that it affords a water route from the interior of Germany to the sea—in this case to the ports of Bremen and Bremerhaven.

"Next to the Rhine, the Elbe is the most important river in

Europe. It is not so deep as the Rhine, and its flow is less uniform. In the lower reaches it has been somewhat difficult to improve because of the unstable character of the river bed. Frequently during dry seasons navigation is impeded because of the low water. The principal natural advantage of the Elbe is that it affords water communication from Czechoslovakia and the interior of Germany to the port of Hamburg, which is the most important seaport of Germany.

"The Oder possesses fewer natural advantages than the Elbe. It is not so deep and has been much more difficult to improve. In the upper reaches above Breslau it has been necessary to canalize the river in order to secure a sufficient depth. The principal advantage of the Oder is that it flows from the Bohemian frontier, through the center of Germany, to the port of Stettin. Both the Elbe and the Oder with their connections form water routes to the thickly populated district around Berlin. The Elbe flows on the west and the Oder on the east, and both rivers are connected with Berlin and with each other by means of several short waterways.

"A number of the canals of Germany and France are unprofitable, in spite of aid given by the government in such forms as low tolls and correspondingly high rates on competitive railroads. Examples are the Dortmund-Ems, the Main-Danube, the Rhine-Rhône, and the Rhine-Marne canals.

"Holland is a country particularly adapted for the construction of canals because of the low level land and the abundant water supply. Much of the land is below the level of the sea and also of the rivers, and few locks are required. For this reason canal building is far less costly and much more feasible than is usually the case. Almost every town in Holland has water connections with the leading seaports. This explains why about 90 per cent of the traffic in Holland is carried on the inland waterways.

"France has sometimes been called the "Paradise of Canals," for it has more miles of artificial waterways than any other European country, and some of the canals carry a surprisingly large traffic. The total length of the waterways used for navigation in 1907 was 7,418 miles, of which 4,356 miles consisted of rivers and 3,062 miles of canals; but some of the rivers included in this mileage are very shallow and not capable of accommodating a large traffic. Some of the canals are also of little importance.

"The steep gradient and great velocity of the current make the

Rhône difficult to navigate, especially upstream. On the Garonne the gradient to be overcome is almost as great as that of the Rhône, while on the Loire the gradient is somewhat less.

"The Seine, although canalized, is the most important waterway in France, and carried, in 1907, 9,300,000 tons, or more than 25 per cent of the total traffic transported on the inland-waterway system of the country. Its great natural advantage is that it connects Paris with the ports of Rouen and Havre.

"While many of the canals of France carry but a comparatively small tonnage, there are some in the midland, eastern, and north-eastern parts of France that carry a heavy traffic. The Canal St. Quentin has the largest traffic of any of these canals. In 1910 it amounted to almost 7,000,000 tons, which is the maximum capacity of the canal. This waterway has a length of 58 miles and a depth of from 6 to 7.25 feet. Although of comparatively short length, it overcomes a height of 265 feet by means of 25 locks. It also has two tunnels, one of them of considerable length. This is perhaps the best example in Europe of an artificial waterway which, in spite of natural disadvantages, carries an enormous traffic. The reason is that it is a connecting link in a through route from Paris to the coal mines of Northern France and to the Belgian frontier, between which localities there is a movement of traffic in heavy commodities far beyond what the railways can accommodate."

THE DECLINE AND REVIVAL OF COMMERCE ON THE INLAND WATERWAYS OF THE UNITED STATES

The volume and value of internal commerce in the United States is many times as large as the country's foreign trade. Nearly all of this huge traffic was carried by inland waterways until the advent of railroads. The Great Lakes, the Mississippi System, and the coastal streams shared the business, and these natural watercourses were supplemented by 3,000 miles of canals, built before 1875, most of them in the years 1820–60. Except for the Columbia and the Sacramento-San Joaquin rivers, all the navigated waterways of the country lie in its eastern half.

Until about the middle of the nineteenth century railroads in the United States carried little freight, because the lines were few and short, the freight cars were small, and the rates were high. Shortly after the end of the Civil War improvements in equipment and consolidation of ownership had progressed so far that east-and-west water routes began to feel the effects of competition. This was especially marked in the case of the canals linking the interior with the Atlantic Seaboard. The cost of shipping grain from Chicago to the coast by the all-water route was forced down from 24 cents a bushel in 1867 to 6 cents in 1874. At this last figure there remained no profit for the carriers, and the canals became practically disused, including the Erie Canal, which had long been a money-maker. After 1875 traffic on the Great Lakes languished for at least a decade. Before 1880 railroads paralleling the Mississippi System of waterways had paralyzed business both on the rivers and on the supplementary canals. Because of increasing railroad competition, the bulky, shallow draft, side- and stern-wheelers which had enlivened the rivers before 1860 never regained the place they lost during the Civil War, although a few continued to ply on the main stream, particularly between St. Louis and New Orleans. The lesser streams lost all their business, and most of the canals connecting the Great Lakes with the Mississippi drainage were abandoned. During the 1880's waterborne commerce appeared to be on the road to rapid extinction throughout North America.

The Great Lakes were first among inland waterways to recover from the effects of railroad competition. During the decades following the Civil War the uses for iron and steel expanded to a degree without precedent. The rich iron ore fields about Lake Superior, some of which had not hitherto been discovered, were brought into production. Coal, used for smelting the ore, was readily available in the vicinity of the Lower Lakes, and the bulky ore moved by water, which was cheaper than and almost as direct as the all-rail route. At about the same time, the Lake Agassiz Plain was opened up as a wheat-producing country, and grain shipments from the head of Lake Superior to Buffalo swelled the volume of lake commerce. By 1890 the Great Lakes were definitely re-established as an integral part of the internal traffic system of the continent. The "Soo" Canal, between Lakes Superior and Huron, had to be twice enlarged, and finally was supplemented by a second canal, on the Canadian side. The tonnage through the Soo increased eleven times in the last quarter

of the nineteenth century, until it became the heaviest canal traffic in the world. A special type of vessel, designed to facilitate rapid loading and unloading of bulk freight, such as coal, ore, and grain, carries most of this tonnage. Each of these boats of the largest type can carry as much as 2,500 standard freight cars. With specially designed machinery the cargo of these boats is moved in an incredibly short time. The record time for unloading is 3 hours and 5 minutes; the record for loading is $16\frac{1}{2}$ minutes.

The Mississippi River System has been unable to profit from conditions of the sorts which have favored the revival of commerce on the Great Lakes. Increasing movements of coal have been handled in part on the Ohio and its tributaries, but the total tonnage is not large. In spite of the continual expenditure of huge sums authorized by Congress for dredging, harbor works, and other improvements, and regardless of incessant agitation for deep waterways, the business of the Mississippi System continued to decline until the time of the World War. As long as the railroads were able to care for the traffic, they obtained it. Railroad building, however, did not keep pace with the growth in business, and by the second decade of the twentieth century an acute shortage of freight cars was felt whenever shipments were unusually heavy, e.g., at wheat-harvest time. This shortage was so aggravated by the abnormal demands of wartime that the federal government built a number of boats for the Mississippi service.

These were very different from the steamers of the old river days. Each boat is a barge of moderate size; some of them are equipped with internal combustion engines and living quarters for the crew. A unit ordinarily is made up of one power barge and five cargo barges, lashed together. Each unit contains cargo space equal to about 375 box cars of standard size. The barges in service in the St. Louis district carried about 105,000 tons in 1919, the first full year of private operation. In 1923 the tonnage had grown to 710,000. This business centers at St. Louis and Memphis, the Lower Mississippi being the principal artery of trade.

Water traffic on the rivers of the United States seems to be on the verge of revival, but it is too early to hazard a prediction as to the extent of the resuscitation. As yet there is no indication that canals will play a rôle of consequence in this latest phase of river transportation, or that any streams except the major limbs of the Mississippi System will be involved.

PRINCIPAL COMMODITIES SHIPPED ON THE GREAT LAKES, IN MILLIONS OF TONS[1]

	1905	1913	1923
Iron ore	37	55	66
Coal	14	33	33
Stone	No data	No data	10
Grain	6	12	12
Lumber*			

* Data not available—fairly important, though very much less than in earlier years.

SOO CANAL TRAFFIC, IN TONS[2]

	1922
Iron ores, eastbound	42,227,000
Wheat, eastbound	4,593,000
Coal, westbound	9,461,000
Total freight	66,067,000

	1916
Net registered vessel tonnage, approximately	70,000,000
Net registered vessel tonnage of Suez Canal, approximately	12,000,000

[1] Annual Reports of the Lake Carriers Association.

[2] United States Department of Commerce, Bureau of Foreign and Domestic Commerce, Mis. Series No. 119, *Inland Water Transportation in the United States* p. 54. Washington, 1923.

SHIPMENTS AND RECEIPTS OF FREIGHT AT PRINCIPAL UNITED STATES GREAT LAKES PORTS, 1923, IN HUNDREDS OF THOUSANDS OF TONS[1]

	Shipments	Receipts
Two Harbors, Minn.	72	3
Duluth-Superior, Minn.-Wis.	441	140
Ashland, Wis.	67	7
Marquette, Mich.	29	3
Escanaba, Mich.	60	3
Milwaukee, Wis.	5	50
Chicago–South Chicago, Ill.	13	122
Indiana Harbor-Gary, Ind.	8	78
Calcite, Mich.	75	..
Detroit, Mich.	2	43
Toledo, Ohio.	84	23
Sandusky, Ohio.	28	6
Lorain, Ohio.	31	44
Cleveland, Ohio.	17	111
Ashtabula, Ohio.	48	118
Conneaut, Ohio.	29	100
Buffalo, N.Y.	33	109

FREIGHT SHIPMENTS ON THE MISSISSIPPI RIVER SYSTEM, AND ON THE GREAT LAKES, 1916[2]

Waterway	Million Tons
Ohio System	15.6
Missouri System	.2
Upper Mississippi System	.4
Lower Mississippi System	11.6
Total Mississippi System (Coal constituted 71%)	28.0
Great Lakes	125.4

[1] *Report of the Chief of Engineers, United States Army, 1924*, pp. 11–13. Washington, 1924.

[2] Compiled from United States Department of Commerce, Bureau of the Census, *Transportation by Water, 1916*. Washington, 1920.

PRODUCTS OF THE OCEANS

The oceans are vast storehouses of a number of valuable natural resources. Since the very earliest times coastal and island people have caught fish, which in many instances has been a major element in their diet. It is only within recent generations, however, that the varied products of the seas have been exploited on a large scale. This has been made possible by the use of steamers in the fishing business, by refrigeration and rapid land transport, which permit the sale of even the most perishable commodities at points far inland, and by the invention of numberless novel uses for sea products.

Sea products are extremely varied in character. Throughout the world sea water is evaporated in order to get salt. Kelp, a seaweed abundant along some coasts, is the raw material from which iodine is extracted. Most sea products valuable to man, however, are of animal origin. Some of these are mineral deposits of low forms of life, including shells for jewelry and buttons, corals, and pearls. Others are true animal products—sponges, shark skin, whalebone, sperm oil, sealskin, and so on. By all odds the most important resources of the oceans are those forms of life which are used for food and fertilizer. These include a large number of species, from the sessile oyster to the wide-ranging whale.

All the sea products are strikingly localized in distribution. Even salt is far more abundant in warm and inclosed waters into which few streams flow than in cold seas which receive the discharge of large rivers. The temperature and density of sea water markedly affects the distribution of animal life, and of the plants on which the animals depend for subsistence. The warm waters of low latitudes are noteworthy for their abundance and variety of life forms, many of which are, however, useless to man. The cooler waters of middle latitudes are the habitat of fewer varieties, which tend to segregate themselves into "schools" at certain seasons. A large proportion of these species are edible, and their gregarious habits facilitate catching them. Nearly all the common fish of commerce come from these cool waters: herring, cod, mackerel, halibut, sole, salmon, shad, oysters, clams, lobsters, shrimps, and many others. In the cold waters of high latitudes whales and seals make their headquarters.

Besides varying in character and abundance with temperature of the water, marine life is closely related to the depth and the character of the bottom. The vegetation upon which all marine animals directly or indirectly subsist is confined to levels relatively near the

surface which are penetrated by the sun's rays. Some plants float, without being rooted to the sea floor, and these may be found in mid-ocean, as well as near land. Most vegetation, however, is rooted to the ocean bottom, and therefore lives only in shallow water. Thus it happens that animal life is far more abundant in shallow waters than in deep oceans. The principal home of all the valuable sea products is on the "continental shelves," those margins of the continents upon which the world-ocean has encroached. Over the continental shelves the water is not more than 100 fathoms (600 feet) deep, and the chief regions of marine life are places where these shallow waters are most extensive—the Banks of Newfoundland, the North Sea, the shoals off East Asia, the shallows about the East Indies and the West Indies, and the waters east of Patagonia.

The fishing industry centers mainly on coasts adjacent to these extensive fishing grounds. In these regions the business is diverse—there is gathering of the relatively immobile shellfish, netting of fish which frequent coasts or coastal streams, and catching of the freer ranging species some distance out at sea. In the vicinity of Japan, and particularly in the North Sea and off the coast of Eastern North America, the industry is carried on on a large scale, not only to supply the local needs of the fishing communities, but for export. In the warmer waters of the low latitudes, most of the catch is taken to supply local needs.

In addition to the fishing on the wider parts of the continental shelves, there is an industry of more or less importance along all coasts, even where the deep ocean lies close to shore. In some places the resource is sufficient to make fishing an important occupation, as in the salmon and cod and halibut catching off the west coast of North America, and the sardine fishing of the Mediterranean Sea and the Bay of Biscay.

STRATEGIC OCEAN LOCATIONS

The supreme importance attached to ocean trade and its flow through traffic lanes is attested by the following résumé of political control of the principal traffic foci. Without overseas shipping, civilization would be far less varied than it is, and economic and

social interdependence would not exist beyond the confines of individual continents.

From one point of view the earth consists of a continuous body of water covering three-fourths of the surface of the globe. Out of this "world-ocean" rise land areas of varying sizes, from the gigantic islands which are called continents, to tiny islets, each made up of a single rock.

Europe, Asia, and Africa together form the largest connected land mass, to which the name the "World-Island" has been given. Next in size ranks the double continent of the Americas, followed by Australia, and the lesser land units which commonly are spoken of as islands.

The world-ocean was an impassable barrier to primitive peoples, except where chains of islands served as stepping-stones from one land to another. In the world of today, however, the ocean no longer is a barrier to movement, although it remains inhospitable to fixed habitation. It has become the passway from one continent to another, a principal route from one coast to the other of the same continent, and the avenue of travel around the world. Indeed, the demand for ocean passage has become so imperative that canals have been dug to sever Africa from Eurasia, to separate the Americas, and to convert a number of peninsulas into islands.

The chief significance of the world-ocean is its service to commerce. Without ocean trade few regions of contrasted climate could exchange their diverse agricultural and forest products, many minerals could not be used because of their remoteness from market, the few large manufacturing regions could not distribute their varied products to the far ends of the earth, and the world would be divided into numberless isolated areas, ranging in size from continents to the tiniest oceanic islands.

It must not be supposed that ocean trade and travel is spread equally over the whole water surface of the earth. On the contrary, there are well-defined "lanes" of commerce. These sea lanes connect land regions which have goods to exchange with each other, and the volume of traffic traversing them varies with the productivity of the lands. Humid climates in middle latitudes and plains with fertile soils are the most generously productive types of regions on earth, and where these favorable conditions are combined with a rich endowment in minerals, manufacturing is likely to be important. This combination of environmental conditions exists in Northern Europe

and in Eastern North America, and the trade which plies between these two regions is the largest overseas commerce in the world. Conversely, in the Polar Seas there is little or no traffic, partly because ice impedes navigation, but chiefly because the polar regions furnish no commodities for exchange.

The exact paths followed by shipping are determined by minor factors of environment. Other things being equal, a coast line provided with good harbors is used for terminals of ocean navigation in preference to a coast line having inferior harbors. Thus the chief ports of the Atlantic Seaboard of North America lie between the St. Lawrence estuary and the Chesapeake Bay, south of which the coast is festooned with shifting sandbars. En route from one trade region to another the traffic may be deflected because of intervening land masses, or drifting ice. For instance, the ships crossing the North Atlantic Ocean from New York swing around New England, and at certain seasons avoid icebergs by adhering to a southerly route. Wherever possible, trade routes run via points along the way which serve as crossroads.

Important traffic foci lie where narrows between continents direct shipping into defiles. The Panama Canal is a notable example. Where Asia, Africa, and Europe meet, there is a succession of constrictions which, together, form a strategic chain. The key points in this chain are Gibraltar, at the entrance to the Mediterranean Sea, Malta at its waist, the Dardanelles and the Bosporus at the entrance to the Black Sea, and the Suez Canal and the Strait of Bab-el-Mandeb at the entrances to the Red Sea. The Strait of Malacca, between mainland Asia and the offshore island group which extends to Australia, is similar in character. In a lesser degree, but for the same reason, straits which give approach to land-locked seas have strategic importance. Examples are the Sund, at the entrance to the Baltic Sea, the Strait of Ormuz, opening into the Persian Gulf, and the Florida Strait and the Yucatan Channel, the two gateways of the Gulf of Mexico.

Certain islands are located at crossings or convergencies of trade routes, and so possess strategic value for trade. The British Isles lie at the front door of Continental Europe. The Hawaiian Islands are a point of call for many ships which traverse the Pacific from America to Asia, and from North America to Australia and New Zealand. Thus they have become a center of exchange in mid-Pacific. Barbados, in the West Indies, stands athwart the ocean routes between

the Old World and Middle America. The southern tip of Africa is a focus of part of the shipping between Europe and Asia, and for certain round-the-world traffic. Ceylon occupies a similar position for trade in the Indian Ocean.

The political control of strategic ocean locations is highly prized, both for the profits which the trade brings in, and because trade foci, of the types which have been enumerated, are convenient fueling stations and may be used as naval bases in time of war. Naturally enough the leading maritime nation of the world, Great Britain, controls some of the most important of these points. Gibraltar, Malta, Suez, and Aden give the British Empire an effective hold on the main route between Europe and Asia, and South Africa performs the same service for the secondary route, which circles the Cape of Good Hope. Possession of Ceylon, key point in the traffic around India, and of Singapore, the guardian of the Strait of Malacca, completes British domination of the Asiatic trade. In the Western Hemisphere, Britain holds Barbados, but the other strategic points of prime importance are controlled by the United States, the Panama Canal, and the Hawaiian Islands by ownership, and the two entrances to the Gulf of Mexico by virtue of a naval base on the island of Cuba. Political control of the remaining traffic foci is scattered. Persia holds the gate to the Persian Gulf, but its importance is trifling. The Sund is practically Danish water. The Germans found it so irksome to be bottled within the Baltic that they constructed the Kiel Canal as an all-German entrance. The Dardanelles and the Bosporus have threatened the peace of Europe time and again since the Trojan War. During the World War a mighty effort was made to wrest these narrows from Turkey, and the Peace Treaties created an international zone on both sides of the straits. Mutual jealousy among the Allies nullified this arrangement almost immediately, and Turkey once more is astride the coveted channel.

THE ICE PATROL ALONG STEAMSHIP ROUTES IN THE NORTH ATLANTIC[1]

"The spring of 1923 will complete ten years of ice patrol service in the North Atlantic. During this period scientific investigation of the ice regions has been carried on with the object of increasing our general knowledge of these regions, and also of securing a more effective management of the patrol. Up to within a few years the behavior of ice in the Atlantic was a matter of conjecture. Today charts are available showing the drift of bergs from the time of leaving the Labrador coast, the courses followed by these bergs being as carefully plotted as the track of a ship. Conditions are subject to much variation from year to year. Some years produce large quantities of ice; other years bring scarcely any. In some years the ice is held up in high latitudes; in others it drifts far south.

"Ice which drifts south into the Atlantic every spring constitutes a great menace to steamships plying between Europe and the United States. In the days of slow steamers most of the vessels followed a Great Circle course between the two continental ports, which carried them through the ice zone a large portion of the year. Since the advent of the large and fast passenger steamers, agreements have been entered into whereby definite routes have been established to the southward of the normal ice zone. Regular steamship tracks across the North Atlantic now pass just south of the Tail of the Grand Bank, the westbound lane lying somewhat north of the eastbound route, in order to minimize the danger of collision between vessels. These lanes bring the boats perilously close to the southern margin of the berg drift.

"If the ice zone were fixed, nothing further than this establishment of definite routes for steamers would be required to assure reasonable safety along the routes, but, as previously indicated, the limits of the ice fields and the bergs vary considerably in location as well as in season, and consequently a vessel might sail on a course that was clear at the time of her departure but collide with ice which had drifted into her path when she reached the vicinity of the Newfoundland Banks.

[1] Adapted from: Edward H. Smith, "Some Meteorological Aspects of the Ice Patrol Work in the North Atlantic," *Monthly Weather Review*, L (1922), pp. 629–631, U.S. Weather Bureau, Washington, 1923; and *Pilot Chart of the North Atlantic Ocean, March, 1923*, Hydrographic Office, United States Navy Department, Washington, 1923.

"During the past few years, steamship companies have co-operated with the United States Hydrographic Office to shift the tracks to the southward one degree of latitude (69 miles) during the season of maximum ice. The dates for the change in routes vary from year to year with the number of bergs, but the southern route is followed as a rule between April 1 and July 15.

"The establishment of the ice patrol followed directly the 'Titanic' disaster, when the then largest ship afloat was sunk on the night of April 14, 1912, by striking an iceberg off the tail of the Great Bank of Newfoundland. In November, 1913, an international convention met at London, and among other subjects discussed was the practicability of patroling the ice regions. It was agreed to establish a permanent International Ice Patrol Service, and the United States government was invited to undertake the management of the service, the expense to be divided among the signatory powers in proportion to the amounts of their respective ship tonnages.

"The first work has two aspects: first, and of the utmost importance, is the determination of the variable limiting lines of menacing ice, and the dissemination of the information for the guidance of shipping, and second, and co-ordinate with the first, is the making of such oceanographical and meteorological observations as will determine the causes of these variations, thereby increasing our knowledge to insure means of greater safety for life at sea.

"A continuous patrol is maintained by two United States Coast Guard cutters capable of keeping at sea in all kinds of weather, each one alternately taking a two weeks' tour of duty and then being relieved by the other. When the ice scout approaches the region, it collects all information from nearby vessels, and proceeds to search the area south of latitude 43° for signs of ice. It is the duty of the patrol to maintain contact with the southern, eastern, and western limits of ice as they vary in position throughout the season, and to broadcast this information to all approaching ships.

"It can be seen from this duty as briefly described that a thorough knowledge of ice movements is absolutely necessary. In conjunction with its scouting duty, the ice patrol secures scientific observations relating to the area. Daily reports also are forwarded to the United States Weather Bureau.

"The three great ocean currents in the northwest Atlantic are well known, viz., the East Greenland, the Labrador, and the Gulf Stream. The East Greenland Current is an overflow from the north

polar basin of an accumulated mass of fresh water which has been discharged from northern Eurasian rivers and augmented during the summer by the water from melted ocean ice. The escape is southward past Jan Mayen along the east coast of Greenland, where the current bears great masses of heavy sea ice. The number of bergs is comparatively small, due to the scarcity of glaciers along the east coast. The East Greenland Current rounds Cape Farewell and continues northward along the west coast of Greenland to 65° N., where it begins to throw off branches westward to the Labrador Current. A northward moving current is found along the coast as far as Cape York.

"The Labrador Current has its source in Arctic regions, where the current is known as the polar drift. Upon passing through Davis Strait the current assumes stream flow and becomes known as the Labrador Current. The major and definite stream flows southeasterly, reaching and completely flooding the northern part of the Newfoundland Banks, where it branches. A small stream sets westward through the "Gully" under the Newfoundland headland; large quantities spread eastward in expansive surface layers, and a definite stream continues southward down the east side of the Grand Banks. The latter is that portion of the Labrador Current which carries the bergs southward, constituting a menace on the steamship tracks.

"When the Gulf Stream leaves the coast of the United States it gradually changes course to the eastward, and by the time it reaches the Tail of the Bank its flow is east. Just east of the Grand Banks (at about the 47th or 48th meridian) it breaks sharply and flows in a northerly direction. In doing this it spreads fanshape to form many bands of warm water and expansive ocean drifts; farther east it is of no interest to this discussion.

"In detail the oceanic circulation at the Tail of the Bank during the ice season may be described as follows: The Labrador Current impinges itself on the northern edge of the Gulf Stream. At times this push is strong enough to split the Labrador Current into an east and west branch. In this case the stronger branch determines the berg drift, the relative strength of the branches probably depending upon the angle of impingement of the two currents. The conflict of the two currents, together with the position of the Bank, produces a frictional arresting of the Gulf Stream on its northern edge, which in turn swings it in sharply to the north and northwest immediately

after passing the Tail. This inshore westward swirl of frictional bands of Gulf Stream water sets up an interlacing movement of the two waters. In the vicinity of the Tail the surface temperature of the Labrador Current during April is 32° F., and in June its temperature rises to 40° to 44° F.

"In the consideration of ice, it is necessary to make a distinction between field ice and berg ice. Field ice, formed by frozen Arctic Sea water, is, like berg ice, under the control of the winds and the surface currents. As a rule, field ice appears off the east coast of Newfoundland the latter part of January, coming down in a strip 50 miles or so in width, the position of which indicates the axis of the Labrador Current. About two weeks later the field ice has spread over the northern part of the Grand Banks off Newfoundland, extending from the south coast of Newfoundland sometimes as low as 43° north latitude and some of it westward to the Nova Scotia coast. Field ice is very quickly melted in the lower latitudes, so that by the latter part of April the Banks area is generally free from it. Northward off the Newfoundland coast it is found even in summer.

"Most of the icebergs in the North Atlantic represent wastage from the glaciers on the west coast of Greenland; a few come from the east coast, while many have their source in the Smith Sound region and to the northward. Greenland, with the exception of a small strip of its southern coast line, is completely covered by a heavy ice cap. The annual snowfall on this ice cap, though not excessive, represents a large amount when one considers that there is little melting in the high latitudes. This causes a constant increase to the ice sheet. This vast expanse of ice is continually working off slowly toward the sea, in lines of least resistance. Icebergs are formed by the breaking off of masses of ice from glaciers, which project into the deep water of the sea. There is one glacier in West Greenland that furnishes on the average one iceberg a day; there are probably no less than twenty similar glaciers in the north. Bergs are in general much more dangerous than field ice, especially south of the Tail of the Bank. The bergs drift down from the middle of March to the middle of July, and sometimes later. The maximum number of bergs is found during the latter part of May and the first part of June. As summer advances the temperatures of the waters that are infested with bergs during the spring rises. By the middle of July it is unusual to find bergs south of the 43d parallel.

"The procession of ice from the region of Smith Sound, in latitude

78° N., to the Tail of the Grand Bank of Newfoundland, in latitude 54° N., a distance of more than 2,000 miles, is a very striking and majestic phenomenon. Many icebergs ground along the Labrador coast, as the set of the current, due to the rotation of the earth, tends toward that shore. Many bergs ground on the northern slopes of the Grand Banks, a few are set through the Gully but do not drift far westward along the south coast, while many others continue their passage down the east side of the Grand Banks. It is these last mentioned bergs which constitute the great danger to shipping.

"To date no means have been devised whereby the presence of an iceberg can be detected during fog or darkness. The presence of cold water does not indicate that there is ice in the vicinity, but if the sea water remains at 60° F. or above, the danger of encountering ice is very much less than otherwise. The Coast Guard vessel on ice patrol keeps a corrected up-to-the-hour temperature chart of the sea water in the vicinity of the Grand Banks, having learned by experience that this chart furnishes the key to the ice situation.

"It may be of interest to know that the Patrol often receives reports of bergs 300 and 400 feet in height and a half mile long. Of the two largest bergs observed by the Ice Patrol during the last four years, one, by sextant angle measurements, was 248 feet above the water and the other was 1,690 feet from end to end."

LATITUDE AND LONGITUDE DETERMINATION ON SHIPBOARD

Latitude ordinarily is determined at noonday with a sextant. The sextant is a small instrument which the observer holds in his hands and sights on the sun. A movable arc registers the angle between the line of sight and the horizontal, commonly called the "elevation of the sun." At noon the sun is as many degrees from vertical as the observer is degrees away from the parallel over which the sun is vertical.

Longitude ordinarily is determined by means of a chronometer. The chronometer is an accurate clock kept set at the time of Greenwich, England. The meridian of Greenwich is 0°. When the sun is at its highest point, that is, when it is noon at the point of observation the

chronometer is read. For every hour's difference between the chronometer reading and twelve o'clock, the difference in longitude is 15° of longitude; for every minute's difference in time there is 15′ difference in longitude.

THE ENVIRONMENTAL BACKGROUND OF PORTS

The volume and variety of commerce transacted in a port city is closely associated with environmental factors which condition port growth throughout the world. These may be grouped under three heads: (1) the size and productivity of the area tributary to the port, (2) ease of access to the tributary area, and (3) suitability of the harbor site.

Unless a port serves one or more highly productive regions, its business is bound to remain small in volume. The simplest type of region tributary to a port is the area immediately inland, often called the port's *hinterland*. The capacity of this region to produce commodities of commerce is limited by its size, climate, land forms, and natural resources, i.e., by its natural environment. Thus the region tributary to Savannah, Georgia, being smaller than the region tributary to New Orleans, produces fewer goods for exchange through its port. Or again, the region tributary to Calcutta, having a productive climate, gentle relief, fertile soils, and coal deposits, yields more trade than a region of equal size tributary to Tripoli, in North Africa.

The quantity of produce of a port's hinterland is only one element in its commerce, however. The character of the output is of great moment, because the commerce passing through a port is confined to goods which bear exportation. For example, raw cotton is largely exported from regions of production, whereas corn generally is consumed within the production area. The state of Georgia raises large quantities of both corn and cotton, but Savannah, its chief port, exports much cotton and almost no corn.

The variety of output from the hinterland exercises a profound influence on the amount and character of business done in a port. For instance, the hinterland of the Tyne Ports on the east coast of England is rich in coal, and their trade consists mainly in exporting coal, with some business in iron ore and iron and steel goods. Liverpool, on the west coast, is the port for a hinterland devoted to the

manufacture of textiles, pottery, iron and steel goods, and scores of other commodities; hence its export list is extremely varied and lengthy. Inevitably the business of the Tyne Ports is simpler than that of Liverpool.

In many places, especially on plains, the regions tributary to two or more ports may not be clearly set off from each other. In such a case the port most favorably situated may obtain the lion's share of the business, or the trade may be divided according to its character. Thus the Interior Plains of North America are tributary to many ports, from Montreal to Galveston.[1] New York, being on the whole the most favorably situated, carries on the largest proportion of the total business, including all classes of commodities, but Montreal is the chief export port for wheat, Galveston for cotton, and so on.

A type of tributary area quite different from the hinterland is reached from the port by coastwise water routes. Vessels engaged in the coasting traffic pick up and discharge cargo at a number of points up and down the coast, but use one port as a collecting and distributing center. At this central port, called the *entrepôt*, vessels from overseas put in to leave goods for later distribution along the coast, and to pick up the local produce which has been left there by the coasting ships. An *entrepôt* is likely to develop in regions where inland communication is inferior, or where few harbors are available. Zanzibar, an island off the east coast of Africa, for many years was the *entrepôt* for all the coasting trade between the Gulf of Aden and Delagoa Bay. Harbors were few and poor, inland communications were restricted to caravans of porters, and towns located on the mainland were subject to raids by the aborigines. Another case is the island of Hong Kong, where the British established an *entrepôt* in the days when main land ports of China were forbidden to foreigners by Chinese law. In both these cases the traffic available at any one point along the coast was at first too small to warrant the establishment of a world-port, but, by using one place as a collecting and distributing center, profitable business could be transacted. As trade has increased, and communication with the interior has improved, *entrepôts* have tended to disappear or to become ports of the ordinary type. Thus, Zanzibar has lost nearly all its trade to Mombasa, Dar-es-Salaam, and Beira, and Hong Kong now shares the trade of South China with half a dozen or more important ports.

[1] It may be noted that the Mississippi Basin is not immediately inland from the Atlantic ports. Hence it can be called part of the hinterland of those ports only by using the word loosely.

An *entrepôt* of distribution may persist for certain commodities for an indefinite period, so long, in fact, as the quantity of those commodities consumed within the tributary area does not warrant the establishment of branch or competitive houses in other ports. Many luxuries from the Orient, including coffee and tea, are received in bulk at London or Rotterdam, two leading *entrepôts*, and are afterward distributed to the four corners of Europe, and even to the Americas. Some of the advantages of this practice are: (1) shipment in large bulk over most of the journey, (2) prompt reshipment to the destination, insured by the fact that boats bound for every port are constantly in the harbors, (3) warehousing in bulk while awaiting reshipment, and (4) centralization of the office work. New York and Shanghai are other *entrepôts* similar in function to London and Rotterdam, although having a much smaller business of this sort.

Connections between a port and its tributary area profoundly affect the development of both. Ocean transport being cheaper than land transport as a rule, the port which lies at the head of a bay or some distance up a river, is better situated for trade than a port on a straight or projecting coast, because the amount of tributary land within a given radius is greater. Thus Montreal possesses locative advantages over Halifax, and Boston over Provincetown.

Another phase of the relative cheapness of water transport as compared to land transport, appears in the tendency of ports to lie on or near the mouths of navigable rivers, where they can be reached easily from all points on the navigable inland waterways. Most of the major ports of the world have grown up near the head of ocean navigation on streams. Exceptions to this rule fall into some three classes: (1) the region may be devoid of streams of consequence, as are most places having arid, semi-arid, or dry subtropical types of climate; (2) the coast may be mountainous or hilly, as in South Africa, so that streams are beset by rapids near their mouths and are useless for navigation; (3) some navigable streams have silt-choked mouths which debar ingress by ocean vessels; in this event the port is likely to lie offside and to be connected with the navigable part of the river by a canal, as is the case with Marseilles, France, and Alexandria, Egypt.

Even where a port now relies chiefly on railroad connections with its hinterland, it is likely to be situated on a stream because it started there before the day of railroads.

As the connections between a port and its tributary area are improved, the latter commonly is enlarged. Thus, New York City,

originally trading only as far as the Hudson and Mohawk valleys, has extended its tributary area by means, first of canals, later of railroads and lake routes, to include the St. Lawrence Lowland, Southern New England, the whole Middle West, and to a certain extent the South. This aggrandizement of the tributary area of New York has been facilitated by environmental conditions. No other point on the eastern seaboard of the United States possesses such ready natural lines of access to the interior, and the water and rail connections have followed these routes which Nature provided. Competitive ports, such as Baltimore, which are barred out from the interior by rugged country, have been left behind in the race for business and in the growth of population.

Where mountains, swamps, rain forests, or deserts lie between a port and its tributary area, the development of both port and hinterland is impeded. All these conditions prevail in one part or another of Africa, and are in large part responsible for the backwardness of that continent in commerce.

Although a rich region with satisfactory access to the sea is likely to stimulate the erection of a port regardless of the nature of the coast, nevertheless, the existence of suitable harbors enormously facilitates commerce, and generally determines the exact site of port cities.

The environmental essentials for an ideal port city include: (1) a considerable stretch of flat land alongshore easily reached by railroads, to be used for transportation terminals, warehouses, and storage space; (2) a large area back of the flat land suitable for city building, i.e., neither rugged, swampy, desert-like, nor choked with forest growth; (3) an anchorage from the storms of the open ocean, at least on all sides from which storms are likely to come; (4) an expanse of water ample to accommodate several scores of ships, but not so large as to be subject to storms; (5) depth of water close to shore sufficient to accommodate ships of deepest draft (35 feet is sufficient), but not too deep for easy anchorage (more than 100 feet is undesirable); (6) an entrance to the harbor which is wide, straight, and deep; (7) tides of less than 10 feet variation, but with sufficient scour to keep the harbor and its mouth free from silt; (8) a harbor floor of soft but stiff material, to give good hold for anchors; (9) freedom from ice.

Coastlines vary enormously as to the number, distribution, and quality of harbor sites. Two factors are primarily responsible for this variation. One of these is the pitch of the land just below and above sea-level; the other is the recent geological history of the coastline.

Where the relief is strong and mountains or hills dive abruptly into the sea, little flat land is available for port facilities or city building. Water is deep near shore; it may be too deep. The lower ends of valleys are likely to form deep indentations suitable for harbors. Where the relief is low, and plains slope gently beneath sea-level, there is abundant land for the city, but the water is likely to be shallow near shore, and a heavy surf some distance out generally presents an additional obstacle to landing.

The geological processes occurring along a shoreline modify its configuration and furnish a key to its character. Waves and currents tend to cut down elevations in the shallow sea and to deposit the material thus gathered into depressions. Thus the sea bottom near shore tends to become relatively smooth. These same agents wear down headlands, fill inlets, and so smooth and regularize the coastline. Therefore, coasts which in the recent geological past have been gradually emerging from the sea are extremely regular, and such harbors as do exist are likely to be shallow and difficult to enter. In contrast, coasts which in recent geological times have been sinking below sea-level are likely to be decidedly irregular, with many excellent harbors, for nearly all land surfaces are more uneven than sea bottoms, and drowning a land surface results in indentations where were valleys, headlands where were hills, deep water over former river channels, and so on. Still other harbors are independent of either subsidence or emergence of the coastline, but are made by the action of volcanoes, glaciers, and above all, rivers.

One of the most widely distributed types of harbor is that formed by a river mouth. Along regular coasts the mouths of streams are likely to be the only havens of refuge, and even where other bays exist, a port on the river has the advantage of being the terminus for the river traffic as well as for the ocean vessels. Moreover, the lower valley of a large stream is likely to be highly productive. For these reasons many of the world's leading ports lie at or near the mouths of rivers. By all odds the largest group of river mouth ports are those on deltas, where the high productivity and large size of the tributary area combine with easy river transport and an even and marshy coastline to locate the port upon one of the distributary streams of the lower river. Rotterdam, Antwerp, New Orleans, Shanghai, Canton, Calcutta, and Pará are some of the outstanding river ports on deltas. The disadvantages of river-mouth harbors are notorious. The lower courses of large rivers are subject to silting,

and there is no tidal scour to carry off alluvial deposits. Hence ships are likely to run aground unless constant dredging is maintained in the lower course of the stream and some distance offshore. Jetties have been built at the mouth of the Mississippi to narrow the channel, and so increase its velocity and ability to carry sediment. Formerly ocean vessels had to anchor seven miles off Buenos Aires because of shallows in the Plata; a dredged channel now leads to the wharves. Bars off the mouths of the Yangtze and the Ganges distributaries interfere with easy access to Shanghai and Calcutta. Few rivers are wide enough to permit the construction of piers and slips at right angles to the shore. Therefore boats must moor alongshore, and unload and load from one side only, unless lighters are used. Where the port is located some miles upstream, as is usually true on deltas, ocean boats waste much time in navigating the stream, where they are forced to sail very slowly in order to avoid collision or running aground.

Probably the ideal type of harbor occurs where a plain has been submerged so as to drown the sea ends of its valleys. The deep embayments thus formed provide commodious and protected anchorage, they are relatively wide, and so are easily entered and navigated, tidal scour carries off surplus silt, and the port town can be located at or near the head of tidewater, well in the heart of its tributary area. Moreover, submerged rivers possess most or all of the advantages of ordinary rivers as routes for inland transportation, and the part of the channel beneath the sea provides a deep approach to the port across the continental shelf. In most ports on such harbors piers are built out from shore with slips between, thus giving accommodation to the maximum number of ships and permitting lading from both sides of the vessel at once. Tributary streams may form additional units to this type of harbor. For instance, the port of New York comprises not only the lower submerged Hudson River, but also a submerged connection to Long Island Sound and the embayed mouths of the Passaic and Raritan rivers. The ports of England, North France, Germany, and Atlantic North America north of the mouth of Chesapeake Bay lie on submerged river mouths. This list includes many of the largest ports and several of the finest harbors in the world. The disadvantages of this type of harbor include a tendency to shallows in places and the existence of mosquito-infested swamps in the vicinity.

Where an indentation in the coastline is defended from the waves of the open ocean by islands, an excellent harbor may be formed.

Boston, Bombay, and San Diego are examples. Ports located on such harbors are likely to lack the easy access to the interior provided by rivers and their valleys, and so become large cities only when competitive river harbors are wanting. In some cases the islands are tied to each other or to the mainland by bars of sand, which further improve the protection offered by the harbor. San Diego is a case in point.

Fiord coasts are made exceptionally ragged by a continuous succession of deep, narrow, steep-walled inlets, some of which extend scores of miles inland. Bays of this character are heavily glaciated valleys, the floors of which are beneath sea-level. Fiorded coasts rise boldly out of the water, in places reaching elevations of several thousand feet as sheer mountain walls. Harbors are numerous along such coasts, and they possess the advantages of safe anchorage and deep penetration of the land. Nevertheless access to the interior is handicapped by the steep and high coast, and satisfactory port sites are few. Port towns are likely to grow up on the tiny alluvial deltas of the small streams tributary to the fiord. As the town grows, wharves and even streets are built on piling driven into the water, and residences are perched on the steep face of the hill. At Prince Rupert, British Columbia, the terminus of a transcontinental railroad, tons of rock were blasted from the hills and thrown into the fiord in order to provide an adequate port site. Another disadvantage of fiord harbors is the likelihood that the water may be too deep for convenient anchorage. The sharp slope of the coast makes it impracticable to build piers out into the fiord except where deltaic deposits have been laid down. Fiorded coasts are confined to the higher latitudes. The most notable examples are Norway, British Columbia and Southern Alaska, Maine, Maritime Canada, and Labrador, and Southern Chile.

Along coastal plains which, in the recent geologic past, have been emerging, lagoon harbors develop. Waves, currents, and winds have combined to build long, low islands along the line where the surf normally breaks, leaving a shallow, inside waterway between the islands and the mainland. Occasional breaks in the island barrier, which can be used as entrances to the protected waters, are maintained by overflow of stream water from the land and by tidal scour. But longshore currents are inveterate enemies of these channels, and constantly tend to silt them up. Moreover, the alluvium brought down by streams rapidly silts up the quiet lagoons, converting them

into marshland after a time, and the amphibious margins of the original coastline form obstacles to settlement and movement. The only usable sites for ports are on the islands, isolated from the hinterland by a broad expanse of water and marsh. A port to accommodate the ocean vessels of today can exist on a lagoon harbor only by dredging both lagoon and entrance channel, building jetties to deflect silt-laden currents and to increase tidal scour, and constructing costly railroad connections with the inhabited mainland. Obviously, a lagoon harbor is utilized only under the pressure of a hinterland producing a large volume of export commodities. Galveston, Texas, backed by rich cotton and wheat land, and near highly productive petroleum fields, probably possesses the best-developed lagoon harbor in the world. Miles of fill and causeway carry road and railroad lines to the interior, a commodious and easily entered harbor has been dredged, jetties help to maintain a channel open to the sea, and a sea wall has been built to protect the city from the storm waves of the ocean.

Along coasts where waves and currents have had access to abundant supplies of sand a low spit is formed here or there, extending out from the land in such a way as to inclose a small body of water. Where storms are unlikely to approach from the open side, such harbors offer excellent protection, although in some cases submerged bars keep forming across the entrance, and so require continual dredging. Provincetown, a harbor of this type at the extremity of Cape Cod, is protected by a curving sand spit from severe storms, which, in this region, almost always come from the northeast. Spit harbors commonly are formed from alluvium brought down by turbulent streams, which then is moved into position by ocean currents. This type is well illustrated by Loanda and other harbors on the coast of Angola, West Africa. A north-moving current has formed these spits from the material poured into the sea by several rivers. The ports on harbors of this type ordinarily are unable to utilize the parent river for navigation, because of its silt-choked mouth, and its lack of articulation with the harbor. Nevertheless, the stream valley may be utilized for a railroad or other line of communication with the interior.

In a few places the area tributary to a coast wholly harborless is rich enough to warrant the construction of an artificial harbor. Madras possesses a harbor of this type. The extent and character of the works which inclose quiet water vary with the demands of the trade.

Until the volume of traffic compels the construction of a harbor on a coast offering little or no protection from storms, or even from the ordinary waves, vessels anchor some distance from the shore, outside the line of breaking waves, and in water deep enough to avoid any risk of running aground. Goods and passengers are lightered through the surf to the port, frequently at great hazard of loss or damage. In case a storm approaches while a ship is "in port," anchor is weighed and the vessel makes for the comparative safety of deep water in the open ocean. The almost harborless west coast of Middle and South America possesses many port towns where no ocean vessel ever has docked. Inevitably, such ports are small.

VALUE IN MILLIONS OF DOLLARS OF THE FOREIGN COMMERCE OF THE PRINCIPAL PORTS OF THE WORLD, 1913[1]

Port	Imports	Exports	Total Imports and Exports
London	1,236	768	2,004
New York	1,040	865	1,905
Hamburg	1,084	817	1,902
Liverpool	854	950	1,804
Antwerp	623	588	1,211
Marseilles	390	366	755
Bremen	409	268	675
Havre	358	259	617
Calcutta	229	318	547
Buenos Aires	326	164	490
Bombay	203	225	428
Hull	243	169	412
Trieste	176	161	337
Singapore	181	136	318
Shanghai	178	129	307
Genoa	200	102	303
Sydney	152	151	303
New Orleans	89	194	283
Yokohama	158	117	275
Manchester	172	102	274
Alexandria	117	153	270
Table continued on next page			

[1] Statistical Abstract of the United States, 1914 and 1915. Bureau of Foreign and Domestic Commerce. Washington, 1915 and 1916.

Note that Rotterdam, Amsterdam, and Hongkong are not in the list because statistics are not available. Rotterdam probably has a total foreign trade of about $1,000,000,000; Amsterdam and Hongkong between $250,000,000 and $500 000,000.

FOREIGN COMMERCE—*Continued*

Port	Imports	Exports	Total Imports and Exports
Galveston	12	256	268
Glasgow	90	177	266
Southampton	124	137	261
Kobe	85	173	258
Montreal	153	99	252
Santos	89	159	248
Boston	160	66	226
Dunkirk	188	36	224
Melbourne	118	86	205
Grimsby	77	107	184
Petrograd	111	69	180
Riga	70	104	174
Bordeaux	89	79	168
Harwich	125	42	167
Rio de Janeiro	127	39	166
Philadelphia	96	65	162
Habana	98	48	146
Baltimore	34	110	144
San Francisco	67	63	130
Tyne ports	55	64	120
Cardiff	33	84	116
Leith	77	35	112
Seattle	55	55	110
Barcelona	79	30	109
Bristol	88	20	107
Constantinople	74	29	103
Naples	61	38	100
Fiume	44	54	98
Montevideo	30	68	98
Vera Cruz	41	42	83
Odessa	34	45	79
Valparaiso	58	7	65
Canton	23	41	64
Tampico	23	40	63
Osaka	37	21	57
Belfast	47	9	56
Reval	40	11	51

TIDES AND SEAPORTS[1]

"The great ports of the world, almost without exception, are situated on tidal waters. Some of these ports are many miles from the sea—London 50 miles from the mouth of the Thames, Hamburg

[1] H. A. Marmer, "Flood and Ebb in New York Harbor," *The Geographical Review*, XIII (1923), pp. 413–415.

75 miles up the Elbe—and to reach them the ship-borne traffic of foreign and domestic commerce must traverse the tidal waters that connect these ports with the open ocean. These tidal waters thus serve as highways to the seven seas, and for each port the tidal régime in the channel that connects it with the open ocean is a matter of considerable importance.

"In the days of the shallow-draft ship the highway leading from the sea did not possess the importance attaching to it today. Cologne, 210 miles up the Rhine, was in medieval times one of the great Hanseatic seaports, although the channel at that time was less than six feet in depth. But the introduction of steam as the propelling power and the advent of the iron and steel ship, together with the enormous increase in world-wide trade brought about by the industrial development of the past century, make the channel leading to the sea a feature of first importance in the modern harbor.

"The time required for a sailing vessel to cross the ocean, together with its dependence on wind and weather, made impossible the maintenance of an exact schedule for arrival and departure. If the channel leading to the harbor was not sufficiently deep to permit entrance at low water the delay of six hours awaiting high water was not a serious matter, for this delay represented but a very small fraction of the time of the voyage. Now with the time of crossing the ocean counted in days and with a transatlantic liner representing an initial investment of several million dollars, a delay of as much as a quarter of a day at each end may mean the difference between profit and loss; for the profit from the modern leviathan—costly in build and costly in operation as a unit—depends on the number of trips it can make a year.

"The advent of the iron and steel steamer removed the limitation on the size of ships that wood construction had imposed. The larger ship is also the more profitable one to operate, provided the traffic is sufficiently large. And, where the stream of traffic was sufficient, as in the transatlantic trade, the shipping industry responded with larger and larger vessels. The White Star liner 'Majestic,' one of the largest passenger ships, may be taken as type. Having a length of nearly 1,000 feet, a width of 100 feet, and a gross tonnage of 56,000 tons, she carries a crew numbering almost 1,100 and requires a channel depth of not less than 40 feet. As she steams for the harbor of New York at her normal speed of 575 miles per day the 'Majestic' is a far cry from the 'Half Moon' of 80 tons' burden and draft of 7 feet, which

with a crew of eighteen or twenty men Henry Hudson sailed into the same harbor but a little over three centuries ago.

"To permit the deep-draught vessels of modern commerce to enter port, enormous sums have been expended in the effort to maintain a sufficient depth in the channels connecting the seaports of the world with the open ocean. The ideal channel is one sufficiently deep to permit all vessels to enter port at any stage of the tide. Where this ideal was impracticable of realization it has frequently been found necessary to construct a sub-port or twin port closer to sea somewhere along the channel. Obviously this entails extra expense in bringing up the ship-borne traffic, either by rail or by lighter, from the lower sub-port. Despite this, examples of twin ports are not uncommon in Europe. To mention but the more prominent ones we may cite London and Tilbury, Hamburg and Cuxhaven, Bremen and Bremerhaven.

"The tide is the bond that keeps the channel leading to the port in intimate contact with the open sea and its vivifying influences. And the extent of rise and fall of tide in the channel is the factor that frequently determines the type of harbor that must be developed. If the rise and fall of the tide, or more precisely the range of the tide, is over 15 feet the closed-dock type of harbor generally results. This is exemplified by London with a tidal range of 16 to 21 feet and by Liverpool with a range of 15 to 27 feet. A large vessel rising and falling with the tide 15 feet or more twice a day presents a number of problems in loading and unloading. Furthermore, the erection of suitable wharf structures would entail considerable expense. The result in such cases is therefore the closed-dock harbor in which the docks are entered through locks open for a few hours about the time of high water.

"Where the rise and fall of the tide is less than 15 feet and the channel is sufficiently deep the open-basin type of harbor results. In this case piers may be constructed directly into the channel, and a vessel may dock at all stages of the tide, obviating the delay arising in the closed-dock harbor which can be entered or left only near the time of high water. In this regard all the great American ports are fortunately situated, the range of the tide generally being less than 10 feet."

MAP PROJECTIONS

No part of the surface of a sphere can be spread on to a plane without some stretching or tearing or cutting. This may be demonstrated with a section of orange peel or a piece of a hollow rubber ball. The smaller the portion of the spherical surface thus forced to conform to the plane, the less stretching, tearing, or cutting is necessary. The application of these principles to the making of maps brings out the fact that flat maps of *small* areas are almost accurate. This is true, for example, of the topographic maps published by the United States Geological Survey. Nevertheless, if a large number of topographic maps are put together on a flat surface, they do not exactly fit, whereas if the edges are joined in such a way as to leave no overlap at the corners, the resultant map will tend to adopt a spherical shape.

Where maps cover large areas—regions, countries, continents—more or less distortion is bound to occur, in order to locate all places in their proper latitude and longitude. This may be a distortion of *shape*, so that the area mapped on the plane surface appears to have a form different from that shown on a globe; it may be an exaggeration of *size*, so that one part of the map covers more area than the same district as shown on a globe of the same scale; or it may be an alteration of *direction*, so that a place which lies, say, due east of another on the globe does not appear to lie due east of it on the map. In drawing a map of a large area, choice has to be made between correct representation of shape, size, and direction, or a compromise must be adopted.

In making a map of a large area, the parallels of latitude and the meridians of longitude commonly are drawn first, and the representation of the area is then plotted on the grill of parallels and meridians. The simplest method of producing a grill is first to project the desired lines from the globe on to a cylinder or a cone of paper. Either of these when split will conform to a plane surface on which the map may be drawn. On the cylindrical projection both parallels and meridians are straight lines, intersecting at right angles; on the conical projection the parallels are concentric curves, whereas the meridians are converging straight lines. In practice neither of these projections is much used in its simple form, modifications based on mathematical computation having been devised to reduce some of the glaring faults.

The difficulty of securing a satisfactory flat map increases with the size of the area to be shown, and reaches its climax in world-maps.

Three contrasted world-map projections are considered in the following paragraphs.

Mercator's Projection has been in use since the sixteenth century, and is seen more often than any other. It is a modification of the cylindrical projection, being based on a cylinder tangent to the globe at the Equator. Every parallel is shown as having the same length as the Equator, and the meridians are elongated in proportion to the parallels. Anywhere on the map a small area has nearly its true shape, but sizes in the higher latitudes are greatly exaggerated, compared with places in the lower latitudes. For instance, South America and Greenland appear to be about the same size, but in fact South America is nine times as large as Greenland. The parallel of 60° N. or S. is in fact half as long as the Equator, but it is represented as of the same length. Since the meridians are proportionately elongated, a place on the 60th parallel, such as the Gulf of Finland, is drawn approximately four times its proper size.

The objectionable features of Mercator's Projection have led to the invention of many devices for depicting the whole earth without exaggerating size. Mollweide's Homalographic Projection, brought out in 1805, is one of the most successful of these. The parallels are drawn to their true length. The meridians converge at the poles and divide the Equator into equal parts. The central meridian is a straight line, whereas all the others are curves. One hemisphere is shown within a circle, and the other is brought around and flattened out into two crescent-shaped wings, giving the whole map the form of an ellipse. Areas are equal all over the map, but the distortion of shapes is considerable, increasing with distance from the central meridian.

Continued efforts to improve the representation of the world on a single map resulted in the development of Goode's Homolosine Projection, first published in 1924. It is an equal-area projection, accurate to scale within 40° of the Equator. In addition, the distortion of shape is reduced to a minimum by two devices: (1) latitudes above 40° are drawn on a different projection from that used for latitudes below 40°, there being no one projection equally favorable to accurate representation of both low and high latitude regions; (2) each continent is drawn on a separate central meridian, so that no important land area lies far enough from a center to be seriously distorted. This use of several centers for the map is made possible by interrupting the continuity of the projection in mid-ocean. In other words,

instead of greatly stretching the spherical surface, as is done in both Mercator's and Mollweide's projections, Goode's projection cuts it.

In addition to the three projections considered in the foregoing paragraphs there are many slight modifications of these types, and some projections of a rather different nature. Most of the other types are little used, or employed only for specific purposes. There are numerous projections calculated to depict parts of the world. Which of them is selected for a given map depends upon the size of the area to be represented, its latitude, and the purpose for which the map is to be used. For instance, the projection chosen for a map of the United States is unlikely to be employed for a map of Illinois, because of the very different size of the two areas; Brazil and Europe are placed on different projections, because the one lies athwart the Equator, whereas the other is all in one hemisphere, and mostly in the higher middle latitudes; and the projection for a map of railroads in North America might well differ from a map showing the distribution and number of sheep, because for the railroad map accurate directions are important, whereas in the sheep map equality of areas is essential.

HISTORY OF CAR FERRY TRANSPORTATION ON LAKE MICHIGAN[1]

As long ago as 1882 the Flint & Pere Marquette Railroad operated steamers between Milwaukee and Ludington, Mich. They were generally known as "break-bulk" boats, that is to say, the ladings had to be transferred from boats and reloaded into cars on the opposite side of the lake. The growing traffic and the necessity for more routes and gateways from and to the Northwest found the break-bulk boats wholly inadequate, and in 1888 the Ann Arbor Railroad built a boat along entirely different lines and called it a car ferry. Until this system was established for carrying carloads of freight without breaking bulk, Lake Michigan stood as an impassable barrier to the direct and unbroken movement of carload freight.

The directors of the Flint & Pere Marquette voted the necessary expenditures in 1896 for building the first steel far ferry. This has a

[1] Adapted from A. J. Hewitt, in *Pere Marquette Service*, March-April, 1925. Detroit, 1925.

record, I believe, that no other fresh-water boat ever equaled, averaging over 65,000 miles per year since its launching. So well did the management plan its construction, and so practical did it prove, that steel car ferries ever since have been built along the same lines.

These powerful craft, traversing a checker-board path across Lake Michigan, carrying within them each a whole train of loaded cars, have excited the admiration of the marine world to no small degree. Their unrivaled performance in maintaining an uninterrupted period of navigation alike through summer calm and winter storm, is indeed little short of the miraculous. Although the passage across the lake in winter seems perilous and frequently is fraught with danger, yet in the 29 years of operation, the Pere Marquette car ferries have had very few days when their operation was so severely interfered with that it resulted in stoppage of the route. In fact, the periods where ferry operations have been interrupted through weather conditions can be figured in hours rather than in days, and this is a record that cannot be approached by many yard and railroad operations.

When car ferries were first put into commission the shipping public was rather skeptical about intrusting the freight to a boat haul across Lake Michigan. It pictured the car float in New York harbor, where a tug-boat, a bunch of tow on its bow, pushed around an open deck car float. Lake Michigan car ferries are seaworthy ships. Now no second thought is given as to the safety or the likelihood of danger to it.

The Pere Marquette fleet now consists of seven modern steel car ferries. Interesting disclosures result from a brief survey of the Pere Marquette System and its eastern connections. The distance from Manitowoc to Buffalo via Chicago is 692 miles, whereas via the Pere Marquette car-ferry route the distance is about 522 miles, a saving of 170 miles and about 12 hours shorter in running time. This line gives to the shipper in Wisconsin and the Northwest a short, fast, and economical route to Detroit, Port Huron, Toledo, and Buffalo. Likewise the products of the East can be handled advantageously and with despatch to Wisconsin and the Northwest.

INDEX

INDEX

Page references to exercises and textual materials are in roman type; figure number references to illustrations are in bold-face type. In looking up a topic *all* references in the Index should be consulted; illustrations and exercises are of co-ordinate importance with textual materials, for the purpose underlying the organization of this book is to present an effective scheme of study for a given topic, rather than to arrange the materials as in a handbook of ready reference; in most cases textual materials, apart from exercises and illustrations, give an incomplete idea of the treatment of a given topic.

Acres, relation to hectares, **51**

Adelaide, South Australia, climatic data, 190–191

Adobe, 244, 263

Agriculture: in mountain valleys, 182, 193–194, **171, 182–184;** on slopes, 49, 65, **181, 183;** *see also* appropriate climatic types and land forms, economic life

Alexandria, Egypt, foreign commerce, value of, 355

Alluvium, 249, 281; Hungarian Plain, 59; Mississippi Valley, 56–57; **210;** North Lowland of India, 59, **209**

Alpine scenery, 43, 196–197, **165, 166, 185–187, 189**

Alps: passes in, 100–201, 202; pastoral life of, 192–196

Altitude, climate, as affected by, 11–12

Antwerp, Belgium, foreign commerce, value of, 355

Arable land of the earth, 168

Archangel, Russia, climatic data, 190–191

Area of the United States, by states, 293–294

Arequipa, Peru, climatic data, **61**

Artesian wells, North and South Dakota, 277–278, **297;** supplementary source of city water supply, 285, 288

Artificial harbors, 354–355

Aswan, Egypt, climatic data, 190–191, **16**

Atacama Desert, climate of, 113

Athens, Greece, climatic data, 190–191, **17**

Atlanta, Georgia, average monthly temperatures, **145**

Atlas, use of, xxxiv, 8

Austin, Texas, climatic data, 190–191, **23**

Baltimore, Maryland: foreign commerce, value of, 356; wind directions, **155**

Banana picking, **59**

Bananas; *see also* appropriate climate types and land forms

Barcelona, Spain, foreign commerce, value of, 356

Bedrock, 76–78; building materials, 262, 267, **279, 280;** engineering problems related to depth of, 261

Belfast, Ireland, foreign commerce, value of, 356

Berlin, Germany, climatic data, 190–191

Blizzards, 148, 151–152

Bluegrass, limestone basin, 71, 204–208, **268**

Boise River, variations of flow, **319**

Bolivian Plateau: climatic conditions, 128–129; economic life, 130; native animal life, 130; natural vegetation, 129–130

Bombay, India, foreign commerce, value of, 355

Bora, 142

Bordeaux, France, foreign commerce, value of, 356

Boston: Harbor, 352–353, **353;** Massachusetts, foreign commerce, value of, 356

Bourke, New South Wales, climatic data, 190–91

Bremen, Germany, foreign commerce, value of, 355

Brenner Pass, 200–201

Bristol, England, foreign commerce, value of, 356

British Isles, relation of cities to coalfields, **284**

Buenos Aires, Argentina: climatic data, 190–91, **24;** foreign commerce, value of, 355

Bukarest, Roumania, climatic data, 190–191, **29**

Building stone, 262, **279**

Bulk-breaking points, 316–317

Cacao: picking, **57**; *see also* appropriate climate types and land forms

Calcutta, India, climatic data, 131, 190–191, **13**; a delta city, 215, 216, 217

Canada winter wheat acreage, **107**

Canals for navigation: control of, by governments, 328; control of, by railroads, 328; Europe, 324–328, 331–332, **337**; United States, 325–328; *see also* Erie, and Illinois and Michigan canals

Canton, China, foreign commerce, value of, 356

Canyons, 51, 52, 206, 207

Car ferries, on Lake Michigan, 361–362; on the Great Lakes, **340**

Cardiff, Wales, foreign commerce, value of, 356

Cape Town, Union of South Africa, climatic data, 190–191

Centigrade temperature scale, relation to Fahrenheit, **47–48**

Central Europe, land routes, 202–203

Charleston, South Carolina, climatic data, 190–191, **22**

Chernozem, 246

Chicago, Illinois: a railroad center, 92; climatic data, 169, 190–191; effect of the Illinois and Michigan Canal on, 91, 319–321; water-supply and sewage systems, 287–288, **305**

Cirques, 43, 197, **187**

Cities: location on deltas, 215–217; location on plains, 209; location on navigable streams, 316–317; water supply of, 284–289; world, with million or more population, 189

Clay soils, 247, 280

Climate, 6–39; average rainfall, May–October, *see* world-map, map pocket at end of volume; average rainfall, November-April, *see* world-map, map pocket at end of volume; average temperatures for January, *see* world-map, map pocket at end of volume; average temperatures for July, *see* world-map, map pocket at end of volume; continental influence in, 147, 161; marine influence in, 161; types of, 6–39, 103–105, 105–188, *see* world-map, map pocket at end of volume; *see* also East margins of continents in higher middle latitudes climate, East margins of continents in lower middle latitudes climate, Humid continental with long summers climate, Humid continental with short summers climate, Low latitude desert climate, Lower high latitude climate, Middle latitude desert climate, Polar climate, Rainy low latitude climate, Semi-arid low latitude climate; Semi-arid middle latitude climate, Subpolar climate, West margins of continents in higher middle latitudes climate, West margins of continents in lower middle latitudes climate, Wet-and-dry low latitude climate

Climatic data, 131, 159, 162, 190–191, **11–46**

Climatic regions, 6, 103; economic life, 40; *see* world-map, map pocket at end of volume; *see also* Climate, types of

Cloncurry, Queensland, climatic data, 190–191

Clouds, 28

Coal: chief producing countries, 275; economic and political significance of, 77, 264–265; world-producing districts, **282**

Coalfields of the British Isles, relation of cities to, **284**

Coal mining: central Illinois, 288; Eastern Kentucky, **281, 366**; Pennsylvania Anthracite District, **289**

Coal reserves, principal, by countries, 275

Coast lines and harbors, 96–97, 340, 350–355

Coastal plains of unconsolidated marine sediments, 62–63; economic life, 62, **239**; origin, 231; physical characteristics, 62, 63, 231, **239**

Coffee culture, **89**; *see also* appropriate climate types and land forms

Columbus, Ohio, climatic data, 159, 190–191, **27**

Commerce of principal ports of the world, 355–356

Constantinople, Turkey, foreign commerce, value of, 356

Continental climates, 147; *see also* Humid continental climate with long summers, Humid continental climate with short summers, Middle latitude desert climate, Semi-arid middle latitude climate

Continental ice sheets, as related to the surface features of Europe and North America, 234–236; depositional features, 235; erosional features, 235
Continental shelves, 338
Copper, chief producing countries, 276
Corn: culture, **126, 202;** world-acreage, 100; *see also* appropriate climate types and land forms
Cotton: culture, **114;** United States acreage, **108;** world-production, **102;** *see also* Appropriate climate types and land forms
Crop rotation, 241–242
Crops: corn, cotton, rice, wheat, etc.; *see* appropriate climate types and land forms
Cucamonga District, California, economic life, 218–221, **226–229, 231;** physical characteristics, 218–220, **226, 228, 229, 231**
Cué, Western Australia, climatic data, 190–191
Cuyabá, Brazil, climatic data, 190–191
Cyclones: tropical, 121–125; world-map, **97**

Darjeeling, India **96;** climatic data, 131, 190–191, **42**
Davos, Switzerland, climatic data, 190–191
Delhi, India, climatic data, 190–191, **14**
Delta cities, 215–217, 351–352, **219, 223**
Delta plains, 55–58; physical characteristics, 57, **213–215, 219–224**
Drainage, glaciated areas, 65, 70, 236–237; of land in the United States, **252**
Dry-farming, 163, 164–166
Dry subtropical climate; *see* West margins of continents in lower middle latitudes climate
Dunes, 62–63, 228–231, **237, 238;** area of, Belgium, Northern France, and the Netherlands, 229–230, **236;** Cape Cod, Massachusetts, 230, **238;** the French Biscayan coast, 230; the Michigan and Indiana shores of Lake Michigan, 230–231, **237**
Dunkirk, France, foreign commerce, value of, 356
Durban, Natal, climatic data, 190–191

Earth: axis of, 66–67; revolution of, **66**
Earthquakes, 74; destructiveness of, 251–254, **272, 273, 275, 276;** distribution of, 251, 254, **274**
East Greenland Current, 343–344
East margins of continents in higher middle latitudes climate, 23, 159–160; climatic conditions, 159–160; economic life, 160; natural vegetation, 160
East margins of continents in lower middle latitudes climate, 18–19, 142–145; climatic conditions, 18, 19, 142–144, 145, 172–173, **121;** drier phase, 19, **195*b*, 225;** economic life, 18, 19, 144–145, 113–120, 129, 130; natural vegetation, 144
Economic geography, scope of, 3–5
Egypt, irrigation in, 289–290, 304
Elbe River, commercial highway, use as, 330–331
England, inland waterways, 325, 326, 327–328
Entrepôts, 348–349
Erie Canal, 91, 317–319, 326
Erosion, 65, **251, 270**
Europe: spring wheat acreage, **104;** winter wheat acreage, **103**

Fahrenheit temperature scale, relation to Centigrade, 47–48
Fall line, water power, 86
Feet, relation to meters, 49
Fenno-Scandia, economic life, 232–234; native animal life, 234; physical characteristics, 232–233
Field work, place in economic geography, xxxii–xxxiii
Fiord: coasts, 353, **188, 355;** harbors, 96, 353, **354, 355**
Fishing industries, 337–338; herring distribution, **341;** of Fenno-Scandia and Laurentia, 234; of subpolar regions, 185
Fiume, Austria-Hungary, foreign commerce, value of, 356
Flooded alluvial plains, 55–58
Floods: causes of, 313–314, 315; lower Mississippi Valley, 211–215, **216-219;** Ohio River, 313–314; prevention of, 314–315; Tisza River, 313; warnings, 177–178
Fogs: in the North Atlantic, **344;** in the United States, **138**
Forests: and woodlands, United States, **167;** national, United States, **169**
Fort Chipewyan, Alberta, climatic data, 190–191, **38**

Fort Lamy, French West Africa, climatic data, 190–191, **15**

France, inland waterways 324–325, 326–328, 331–332

Frosts, protection of crops from, 135–141, 175, **112**

Galveston, Texas: foreign commerce value of, 356; harbor of, 354, 356, **362**

Geneva, Switzerland, average monthly temperatures, 145

Genoa, Italy, foreign commerce, value of, 355

Germany, inland waterways, 326, 327, 328, 329–331

Glacial outwash plains, 67–68; physical characteristics, 67, **189**

Glacial outwash soils, 67, 281, **257**; Middle Western United States, **254**; Southern Wisconsin and Northern Illinois, **256, 257**

Glaciated areas; *see* Ice-scoured plains and hill country

Glaciers, 196, **185, 187**; areas affected by, **240**; depositional features, 197, **189, 190**; distribution in Southern Andes of Argentina, **191**; erosional features, 43, 197, **185–188, 190**; mountain scenery, as affected by, 196–197

Glasgow, Scotland, foreign commerce, value of, 356

Gold mine, cross-section, 291

Goode's Homolosine Projection, 360–361, **364**

Grazing, 17; cattle, **124, 144, 170, 205**; in mountains, 192–196, **170**; sheep, **143, 145**; *see also* appropriate climate types and land forms, economic life

Great Basin, lacustrine plains of, **264**

Great circle routes, 94

Great Lakes, barriers to land transportation, 92, 361–362, **340**; commercial highways, use as, 92, 333–336, **287, 339**; iron ore movement, **287, 339**; lacustrine plains bordering, 70, **263**

Great Wall of China, 25–26, **147**

Grimsby, England, foreign commerce, value of, 356

Ground water, 79–80; artesian, of North and South Dakota, 277–278, **297**; provinces of the United States, **301**; relation to earth surface, **295**; springs, 278–280, 284, **298–300**; types of occurrence, 280–284; wells, 79, 281, **296**

Growing seasons, United States, **127**

Guinea Coast, climate of, **108–109**

Gulf Stream, 344–345

Habana, Cuba, foreign commerce, value of, 356

Hamburg, Germany, foreign commerce, value of, 355

Hanoi, French Indo-China, climatic data, 190–191

Harbin, Manchuria, climatic data, 190–191, **33**

Harborless coasts, 96, 354–355, **357–361**

Harbors; qualifications as ports, 96, 350; types of, 96, 351–355, **352–362**

Hardpan, 240, 243

Harwich, England, foreign commerce, value of, 356

Havre, France, foreign commerce, value of, 355

High altitude climates in the low latitudes, 11–12, 125–131; climatic conditions, 11, 125–129, 130–131; economic life, 11, 12, 126–128, 130–131, **88–93, 96**; natural vegetation, 126, 127, 129–130

High altitude climates in the middle latitudes, 36, 180–182; climatic conditions, 180–181, 182; economic life, 36, 180, 181, 182, **165, 166, 170–173**; natural vegetation, 180

High latitude climates, 38–39, 104, 183–188; climatic conditions, 103; economic life, 183; **175, 179**; *see also* Lower high latitude climate, Polar climate, Subpolar climate

Highs, 28–29, 31; winds, as related to, 29, **151–153**

Hill country, 49–50; economic life, 49, 210–211, 197–199, 201–202, 204–205; Kentucky "mountains," 204–208, **199–202, 281**; physical characteristics, 50, 210, 211, **197–201, 203–205**; *see also* Ice-scoured plains and hill country

Hill stations, 12, 127, **96**

Hilo, Hawaii, climatic data, 190–191, **12**

Hull, England, foreign commerce, value of, 355

Humid continental climate with long summers, 21–22, 147–150; economic life, 21, 25–26, 149–150, **126, 128, 133, 134, 136, 137, 147**; natural vegetation, 22, 149, **200**

Humid continental climate with short summers, 21–22, 150–151; climatic

conditions, 22, 150; economic life, 21, 150, 151, **125**; natural vegetation, 22, 151
Humid subtropical climate; *see* East margins of continents in lower middle latitudes climate
Humidity: and economic life, 25; relative, 27, 107
Humus, 243, 244
Hurricanes, 19, 121–125; world-map, **97**

Ice in the North Atlantic, 343–346, **344, 346**
Ice-scoured plains: physical features, **242**; and hill country, 64–66; economic life, 64, North America, 231–234, **241, 243, 253**; Northern Europe (Fenno-Scandia), 231–234
Illinois and Michigan Canal, 91, 319–324, **335, 336**; railroad competition with, 222–224; traffic on, 320, 322–323
Illinois Valley, cross-section, **255**
Improved land in the United States, by states, 293–294
India: agriculture, 116–118, 76, 77, 80–82, 90, 94, 181, 183, 184, 222; alluvial plains of, 59, **209**
Inland seas, commercial highways, 92
International Date Line, **351**
Iquique, Chile, climatic data, 190–191
Iquitos, Peru, climatic data, 190–191
Iron: economic and political significance of, 77, 265–266; ore, movement on Great Lakes, **287, 339**; world-producing districts, **283**
Irrigable land in the United States, 300–301, 302; by states, 294
Irrigated land, United States, 293–294, **142**
Irrigation, 300–304; Irrigation: China, **113,119**; Egypt, 289–290, 304, **310**; factors, 85, **319**; India, 303, **80, 81, 184, 306–309**; Mediterranean region, 303–304; Mexican Plateau, **88**; Southern California, **111**; streams for, 82–85; United States government projects, 295–300, 303, **149, 311, 312, 313–318**; Utah, 290–292; wells for, 303, **81, 307**
Island-protected harbor, 96, 352–353, **353**
Islands, strategic locations, 340–341
Isobars, 28
Isotherms, 28

Japanese earthquake of 1923, 252–254, **273, 276**

Kansas: hot, dry summer of 1916, 171; tornadoes, 155, 158
Kashgar, Sinkiang, China, climatic data, 190–191
Kentucky "mountains," hill country, 204–208, **199–202, 281**
Khirghiz, nomadic life of, 166–167, **146**
Khiva, West Turkestan, climatic data, 190–191, **35**
Kilometers, relation to miles, **50**
Khyber Pass, 199
Kobe, Japan, foreign commerce, value of, 356

Labrador Current, 344–345
Lacustrine plains, 69–70, **259–264**; economic life, **259, 260**; physical characteristics, 69, **259–262**
Lago Nahuel Huapi, **189–191**
Lagoon harbors, 96, 353–354, **362**
Lake Agassiz plain, 69, **259–262**
Lakes: barriers to land transportation, 92, **340**; commercial highways, use, as 92, **287, 339**; sources of city water supply, 81, 287–288
Lancaster-Lebanon area, Pennsylvania, soils, **266**
Land area of the United States, by states, 293–294
Land forms, 40–72, 75; economic life, as affected by, 40; major, 41–53; major, world-map, map pocket at end of volume, *see also*, Hill country, Mountains, Plains, Plateaus; minor, 54–72, 75, *see also* Coastal plains of unconsolidated marine sediments, Delta plains, Flooded alluvial plains, Glacial outwash plains, Ice-scoured plains, and hill country, Lacustrine plains, Moraine plains, Piedmont alluvial plains, Plains having residual soils, Valley floodplains, Well-drained alluvial plains; United States, **232**; *see also* appropriate types of land forms
Land routes of trade and travel, 202–204; Central Europe, 202–203; Mississippi Basin, 203–204; North European Plain, 203, Western United States, 204; *see also* Mountain passes
Landes, 230
LaPaz, Bolivia, climatic data, 190–191, **44**

Laterite, 244–245
Latitude: and map projections, 359–360; determination at sea, 346, **348, 349**
Laurentia: economic life, 232–234; native animal life, 234; physical characteristics, 232–233
Lava, 283
Leith, Scotland, foreign commerce, value of, 356
Levees, natural, 56–57
Lille, France, climatic data, 190–191, **26**
Limestone: building material, 262, 267, **279, 280;** water content, 282; soils, 245, 247–248
Liverpool, England, foreign commerce, value of, 355
Location, element of natural environment, 98–100
Loess, 236, 281, **204**
London, England, climatic data, 190–191; foreign commerce, value of, 355; water supply, 285–286
Longitude, and map projections, 359–360; determination at sea, 346–347, **350, 351**
Long's Peak, (near), Colorado, climatic data, 190–191, **46**
Los Angeles, California: climatic data, 145, 190–191, **20;** water supply, 288–289
Low latitude climates, 6–12, 13–14, 15, 104, 105–131, 132; climatic conditions, 103, 121–125; economic life, 132, **84;** *see also* High altitude climates in low latitudes, Low latitude desert climate, Rainy low latitude climate, Semi-arid low latitude climate, Wet-and-dry low latitude climate
Low latitude desert climate, 8, 109–113; climatic conditions, 8, 109–110, 111–113, economic life, 109, 110–111, 132, **70, 95;** native animal life, 110; natural vegetation, 110, **69–71**
Lower high latitude climate, 183; climatic conditions, 183; economic life, 183, **175, 179;** native animal life, 183; natural vegetation, 183, **174**
Lows, 28–29, 31; United States, average paths, **154;** winds, as related to, 29, 151–153

Manchester, England, foreign commerce, value of, 355
Maps, 98–99; coloring, 6; for use with this text, xxxiv–xxxvii; projections, 98, 359–361, **363–375;** *see also* Weather maps and Weather mapping
Markets, Kashmir wool, **92**
Marseilles, France, foreign commerce, value of, 355
Marshes, reclamation of, 222–226
Materials for geographic study, xxxiv–xxxvii
Mediterranean climate; *see* West margins of continents in lower middle latitudes climate
Melbourne, Victoria, foreign commerce, value of, 356
Mendoza, Argentina, climatic data, 190–191
Mercator's Projection, 360, **363**
Meters, relation to feet, **49**
Mexican Plateau, climatic conditions, 127–128; economic life, 128; natural vegetation, 127
Mexico City, Mexico, climatic data, 190–191, **45**
Middle latitude climates, 15–36, 37, 104, 132–182, climatic conditions, 15, 27, 31, 103; economic life, 168; *see also*: East margins of continents in higher middle latitudes climate, East margins of continents in lower middle latitudes climate, High altitude climates in the middle latitudes, Humid continental climate with long summers, Humid continental climate with short summers, Middle latitude desert climate, Semi-arid middle latitude climate, West margins of continents in higher middle latitudes climate, West margins of continents in lower middle latitudes climate
Middle latitude desert climate, 24, 162–163; climatic conditions, 162; economic life, 162–163; natural vegetation, 162, **139**
Milan, Italy, climatic data, 190–191
Mild-winter–mild-summer climate; *see* West margins of continents in higher middle latitudes climate
Miles: relation to kilometers, **50;** square, relation to square kilometers, **52**
Mineral building materials, other than stone, 263, 267; stone, 262, 267, **279, 280**
Mineral resources, conservation of, 270–271

Minerals: deposits of, 76–78; coal, **275, 282, 284**; economic aspect of, 77, 78, 267–270; iron, **283**; population movements, as affected by, 77, 263–266
Mining, 77–78, 268–269; drift, 268, **281, 366**; open pit, 268, **285, 286**; placer, 268–269, **292**; shaft, 268, 288–291
Mining camps: Tonopah, Nevada, **290**; Virginia City, Nevada, 271–274
Mississippi: Basin, land routes, 203–204; Delta, **213, 215, 219, 223**
Mississippi River: alluvial plain, 56, 57, **210**; commercial highway, use as, 88–89, 329, 334, 336, **326, 327, 338**; floods in the Lower Valley, 211–215, **216–219**
Mistral, 142
Modified humid continental climate; *see* East margins of continents in higher middle latitudes climate
Mollweide's Homalographic Projection, 360, **365**
Mont Pelé, 257–260
Montevideo, Uruguay, foreign commerce, value of, 356
Montreal, Quebec, foreign commerce, value of, 356
Morainal areas of East Central North America, **253, 254**
Moraine plains, 64–66; drainage of wet lands, 65, 70, 236–237; economic life, 65, **246, 247, 250**; physical characteristics, 65, 244–251, 271
Moscow, Russia, climatic data, 190–191, 32
Mountain passes, 198–202, **173, 194, 195***a*
Mountain-valley agriculture, 182, **171, 182–184**
Mountains, 42–45; as barriers, 44, 198–199; economic life, 42, 43, 44, 209, **165, 166, 170–173, 181**; origin of, 197–198; pastoral life in the French Alps, 192–196; physical characteristics, 42, 196–197, 208–209, **165, 166, 185–187, 189, 320**
Muck, 246

Naples, Italy, foreign commerce, value of, 356
Natural vegetation: and climate, 6–39; *see also* appropriate types of climate
Netherlands, the: inland waterways, 325, 328, 331; reclamation of wet lands, 226–227, **235, 236**
New Orleans, Louisiana: a delta city, 215, 216, 217, **219, 223**; climatic data, 190–191, **62**; drainage system, **223**; foreign commerce, value of, 355
New York, New York: climatic data, 190–191; foreign commerce, value of, 355; port of, 348, 349–350, **352**; water supply, 287
New York State barge canal system, 318–319
North America, potential use of land, **168**
North Atlantic, commerce of, 339–340; ice patrol of, 342–346
North European Plain, land routes, 203
Nouvelle Anvers, Congo, climatic data, 190–191

Oases, 110–111, **70**
Oceans, 93–95, 338–339; coast lines and harbors, 96–97, 340, 350–355, **352–362**; commercial highways, use as, 338–341; currents in the northwestern Atlantic, 343–346; North Atlantic ice patrol, 342–346; products of, 337–338; strategic locations on, 340–341; surface temperatures, August, **343**; surface temperatures, February, **342**; tides and seaports, 356–358
Oder River, commercial highway, use as, 331
Odessa, Russia, foreign commerce, value of, 356
Ohio River: commercial highway, use as, 88, 334, 336; floods, 313–314
Olive culture, **110**
Omaha, Nebraska, climatic data, 159, 190–191, **28**
Orange culture, **111**
Osaka, Japan, foreign commerce, value of, 356

Palermo, Sicily, climatic data, 190–191, **18**
Panama City, Panama, climatic data, **60**
Pangerango, Java, climatic data, 190–191, **41**
Pará, Brazil, climatic data, 190–191, **11**
Paris, France, climatic data, 190–191
Pasuruan, Java, climatic data, 190–191
Patagones, Argentina, climatic data, 190–191
Peartree Pass, 200
Peat, 246

Peking, China, climatic data, 190–191, **30**
Petrograd, Russia, foreign commerce, value of, 356
Petroleum: chief producing countries, 276; Southern California field, **293**
Philadelphia, Pennsylvania, foreign commerce, value of, 356
Piedmont alluvial plains, 60–61, **226–231**; utilization in Southern California, 218–221, **226–228, 230, 231**
Piedmont plain irrigation agriculture, Mexican Plateau, **88**
Plains, 46–48; economic life, 209; physical characteristics, 209; *see also* Coastal plains of unconsolidated marine sediments, Delta plains, Flooded alluvial plains, Glacial outwash plains, Ice-scoured plains and hill country, Lacustrine plains, Moraine plains, Piedmont alluvial plains, Plains having residual soils, Valley floodplains, Well-drained alluvial plains, Plains having residual soil, 71–72; economic life, **265, 267, 268**; physical characteristics, 71, **265–267, 269**
Plateaus, 51–53; economic life, 51, 209–210; physical characteristics, 51, 52, 209–210
Point Barrow, Alaska, climatic data, 190–191, **39**
Polar climate, 185–188; climatic conditions, 185–188; economic life, 188; native animal life, 188
Population density; *see* world-map, map pocket at end of volume.
Port Darwin, Northern Territory, Australia, climatic data, 190–191
Portland, Maine, climatic data, 159, 162, 190–191, **34**
Portland, Oregon, climatic data, 162, 190–191, **25**
Port Macquarie, New South Wales, climatic data, 190–191
Porto Rico, hurricane of August, 1899, 123–125
Ports, environmental background, 347–355; principal, foreign commerce of, 355–356; qualifications, 350; tides as affecting, 356–358; tributary areas, 347–350, 354
Potatoes, world-acreage, **101**; *see also* appropriate climate types and land forms
Potatoes, early: distribution from Hastings, Florida, **130**, shipments from Southeastern United States, **129**
Precipitation, Northwestern United States, **140**
Pressure of air, 28, 29, 31; winds, 29, **151–153**
Puna, 128–130

Quarrying, 268, **279, 280**
Quito, Ecuador, climatic data, 190–191, 43
Quixeramobim, Brazil, climatic data, 190–191

Railroad shipments, influence of weather on, 173–175
Railroads: winter operation in northern Michigan, 152–154; Railroads, United States, **196**; relation to waterways, 322, 324, 327, 328, 333, 334
Rainfall: average monthly, data for representative stations, 190–191, **11–46**; May-October average, *see* world-map, map pocket at end of volume; November-April average, *see* world-map, map pocket at end of volume; world-distribution, 300, **150**
Rainy low latitude climate, 6–7, 105–109; climatic conditions, 7, 105–106, 107, 108–109; economic life, 106–107, 132, **54–59**; native animal life, 106; natural vegetation, 13, 106; **53–55**
Reclamation, tidal marshes, 223–226, **234–236**; wet lands in the Netherlands, 226–227, **235, 236**
Recreation areas, 17, 43, 63, 65, 135, 181, 234, 280, **165, 166, 243**
Reno, Nevada, climatic data, 190–191, **36**
Reval, Russia, foreign commerce, value of, 356
Rhine River, commercial highway, use as, 90, 330, **332**
Rice, 18, 116–117; world-acreage, **99**
Rice culture, **76, 77, 113, 116–120, 184, 222**; *see also* Appropriate climate types and land forms
Riga, Russia, foreign commerce, value of, 356
Rio de Janeiro, Brazil, foreign commerce, value of, 356
Roosevelt Dam, 296–298, 299, 300, **313**, 314

Rotterdam, Holland, a delta city, 215, 216, 217
Rubber, crude, at Pará, 56; *see also* appropriate climate types and land forms
Rubber plantation, 78

Sailing routes, 347
St. Gothard Pass, 201
St. Louis, climatic data, 63; effect of the Illinois Michigan Canal on, 321; water supply, 286–287, 303
Salt-making, Sambhar Lake, India, 84
Salt River irrigation project, 295–300, 313, 314
Sandstone, building material, 262; water content, 282
Sandy soils, 62, 243, 246–247, 249
San Francisco, California: earthquake, 251–252, 275; foreign commerce, value of, 356; water supply, 289, 302, 303
Santa Ana, 141
Santiago, Chile, climatic data, 190–191, 19
Santos, Brazil, foreign commerce, value of, 356
Sapporo, Hokkaido, Japan, climatic data, 190–191
Saturation of air, 27, 28
Savannas, 115
Scales linear measure, 49–50; surface measure, 51–52; temperature, 47–48
Scope of economic geography, 3–5
Seattle, Washington: climatic data, 190–191; foreign commerce, value of, 356
Semi-arid low latitude climate, 9–10, 115–116, 117; climatic conditions, 9, 115; economic life, 9, 115–116, 117, 132, 84; native animal life, 115; natural vegetation, 115
Semi-arid middle latitude climate, 25–26, 163–167; climatic conditions, 25, 163, 164; economic life, 25, 26, 163–164, 164–166, 166–167, 143, 144–148; natural vegetation, 163, 166
Semipalatinsk, Siberia, climatic data, 190–191
Sensible temperature, 107
Sextant, use of, 346, 348, 349
Shanghai, China: a delta city, 215, 216, 217; climatic data, 190–191, 21; foreign commerce, value of, 355
Shape, element of natural environment, 90–100
Silt, 247
Simplon Pass, 201
Singapore: foreign commerce, value of, 355; Straits Settlements, climatic data, 190–191
Sirocco, 141–142
Size, element of natural environment, 98–100
Soil conditions, agriculture, as affected by, 239–242
Soils, 40–72, 73, 223, 242–243; acid, 224, 240, 246; adobe, 244; alluvial, 249; as affected by land forms, 248; clay, 247, 280; desert, 243–244; eolian, 249–250; forest, 245–246; glacial, 250; glacial outwash, 67, 281, 257; hardpan, 240, 243; humus, 243, 244; lacustrine, 69, 70; laterite, 244–245; limestone, 245, 247–248; loess, 236, 249–250; moist, 243, 244–245; moraine, 64, 65–66, 235, 250, 281, 245, 246, 251; prairie, 246; residual, 71, 248–249, 266; sandy, 62, 243, 246–247, 249; silt, 247; types of, 242–251; volcanic, 244, 245, 248; water content, 280–281
Solstices, 66–67
South Pass, 201–202
Southampton, England, foreign commerce, value of, 356
Spit harbors, 354
Spitzbergen, (Green Harbor), climatic data, 190–191
Springs, 278–280, 284, 298–300
Steel, chief countries manufacturing, 276
Straits, strategic locations, 340
Streams: irrigation, use for, 82–85; *see also* Irrigation; sources of city water supply, 81, 285–287; strategic locations on, 316–317; water power, use for, 86–87, 320; *see also* Water power
Streams as commercial highways, 88–91, 214, 326–333; commercial cities on, 316–317, 349, 351–352, 327, 329, 330; Europe, 329–332, 332, 337; United States, 328–329, 332–334, 336, 326, 327, 338
Submerged river mouth harbors, 96, 352, 352
Subpolar climate, 184–185; climatic conditions, 184, 176; economic life, 185, 175–180; native animal life, 184, 185, 176; natural vegetation, 184, 176

Sugar-cane culture, **85**
Suggestions to students and teachers, xxvii–xxxvii
Sun-heating, latitudinal variations, **68**
Surface waters, 81; sources of city water supply, 284–289; *see also* Lakes, Oceans, Streams
Sydney, New South Wales, foreign commerce, value of, 355

Tampico, Mexico, foreign commerce, value of, 356
Tea culture, **90, 94, 115**; *see also* appropriate climate types and land forms
Teachers, suggestions to, xxvii–xxxvii
Temperatures: average monthly, data for representative stations, 190–191, **11–46**; daily maximum and minimum for coldest and warmest months at representative stations, **60–65**; January average, *see* world-map, map pocket at end of volume; July average, *see* world-map, map pocket at end of volume; relation between Fahrenheit and Centigrade scales, **47–48**
Terrace towns, **258**; of the Upper Mississippi, 237–239, **255**
Terraces: alluvial, 67; artificial, 49, **181, 183, 204**; drift, 67
Thunderstorms, 154–155
Tides, ports, as affected by, 356–358
Tierra caliente, 125, 128
Tierra fria, 125, 126, 127–131
Tierra templada, 126–127
Till, 64, 65–66, 235, 250, 281, **245, 246, 251**
Time, 346–347, **350**; schedule, for use of this text, xxx–xxxii; zones, **351**
Tisza River, **212**; floods, 313
Tomsk, Siberia, climatic data, 190–191
Topographic maps, for use with this text, xxxiv–xxxvi
Tornadoes, 22, 155–159, **135, 136**
Tosari, Java, climatic data, 190–191
Trieste, Austria-Hungary, foreign commerce, value of, 355
Tropical monsoon climate, 114[1]
Troy Grove, Illinois, area, soils, **271**
Tyne ports, England, foreign commerce, value of, 356
Typhoons, 121–125; world-map, **97**

United States, cotton acreage, **108**; forests and woodlands, **167**; forests, national, **169**; growing seasons, **127**; inland waterways, 325–326, 327, 328–329, 332–336; land artificially drained, **252**; land forms, **232**; land in harvested crops, 141; land irrigated, 293–294, **142**; railroads, **196**; spring wheat acreage, **105**; wet lands, **221, 233**; winter wheat acreage, **106**
Unsubmerged river mouth harbor, 96, 349, 351–352, **356**
U-shaped valleys, 43, 197, **186**
Utah, irrigation in, 290–292

Valdivia, Chile, climatic data, 190–191
Valencia Island, Ireland, climatic data, 190–191
Valley floodplains, 55–58, **208–212, 216–218**; floods in the Lower Mississippi Valley, 211–215; physical characteristics, 55, 57
Valley trains, 67
Valparaiso, Chile, foreign commerce, value of, 356
Vera Cruz, Mexico: climatic data, 190–191; foreign commerce, value of, 356
Verkhoyansk, Siberia, climatic data, 190–191
Vesuvius, 255–257
Victoria, British Columbia, climatic data, **65**
Victoria Land (Shore of Ross Sea), Antarctica, climatic data, 190–191, **40**
Virginia City, Nevada, a mining camp, 271–274
Volcanoes: cones, **192,193**; destructiveness of, 74, 254–261, **277, 278**

Water power, 307–313; Water power, development, 306, 309–311, **321–325**; economic factors, 87, 310, 311; fall line, 86; Niagara Falls, 305–306, 312, **325**; physical factors, 87, 307–308, 310, **319**; Salt River irrigation project, 299; streams for, 86–87, **320**; superpower system, 312; United States, distribution, 306–307; World distribution, 308–309
Weather, consequences of, 170–171
Weather Bureau, United States, economic value of work of, 136–138, 140–141, 173–180
Weather-mapping, 27–30
Weather maps, 28; United States, **156–164**
Weather observation, **27–30**, 34

Weather predictions, 33–35; agriculture, as affected by, 175, 176; economic value of, 136–138, 140–141, 173–180; floods, 177–178; frosts, 137–138, 140–141, 175; horticulture, as affected by, 136–138, 140–141, 175, 176; railroad shipments, as affected by, 173–175; shipping, as affected by, 177, 178

Weathering, agents and processes, 239

Well-drained alluvial plains, 59

Wellington, New Zealand, climatic data, 190–191

Wells, 79, 281, **296**; artesian, of North and South Dakota, 277–278, **297**; for irrigation, 303, **81, 307**

Weser River, commercial highway, use as, 330

West margins of continents in higher middle latitudes climate, 20, 145–147; climatic conditions, 20, 145–146; economic life, 20, 146–147, **123*b*, 124, 149**; natural vegetation, 146, **122–124**;

West margins of continents in lower middle latitudes climate, 16–17, 132–135, 141–142; climatic conditions, 16, 17, 132–134, 135, 141–142, 145; economic life, 16, 17, 134, 135, **110, 111, 228, 230, 231**; natural vegetation, 134, **109, 110**

Western United States, land routes, 204

Wet-and-dry low latitudes climate, 9-10, 114–115, 116–121; climatic conditions, 9, 10, 114, 115, 118–121, **83**; economic life, 9, 114, 116–117, 118, 132, **73, 76–82, 85, 87, 90, 94**; native animal life, **87**; natural vegetation, 114, **72–75, 86–87**

Wet lands, coastal marshes, 62, **234, 236**; floodplains, 55–58, **208, 212, 216–218**; glaciated areas, 65; lacustrine plains, 70; United States, 221, **233**

Wheat, culture, **125, 195*b***; world-acreage, **98**

Wheat culture, *see also*, appropriate climate types and land forms.

Wheat, spring, Europe acreage, **104**; United States acreage, **105**

Wheat, winter, Canada acreage, **107**; Europe acreage, **103**; United States acreage, **106**

Wind belts, **347**

Wind directions, Baltimore, Maryland, **155**; Chicago, Illinois, 169

Wind-shift lines, 29, **153**

Winds, 29, **152**; effect on a ship's course, **345**; in the Northern Hemisphere, **151, 153**

Winnipeg, Manitoba, climatic data, 159, 190–191, **31, 64**

Wray, Colorado, climatic data, 190–191

Yangtze, commercial highway, 89

Yokohama, Japan, foreign commerce, value of, 355

Yuma, Arizona, climatic data, 190–191

Zambezi Basin, climatic conditions, 118-121

PRINTED IN THE U.S.A.

PART III
ILLUSTRATIONS

FIGURE
1. World-Map of Climatic Regions of the Continents*
2. World-Map of Average Surface Temperatures for July*
3. World-Map of Average Surface Temperatures for January*
4. World-Map of Average Rainfall of the Lands, May 1–October 31*
5. World-Map of Average Rainfall of the Lands, November 1–April 30*
6. World-Map of Natural Vegetation (in your atlas)
7. World-Map of Major Land Forms of the Continents*
8. World-Map of Density of Population*
9. World-Map Showing Elevations of Land and Depths of Sea (in your atlas)
10. World-Map of Political Divisions (in your atlas)

*In the map pocket at the end of the volume.

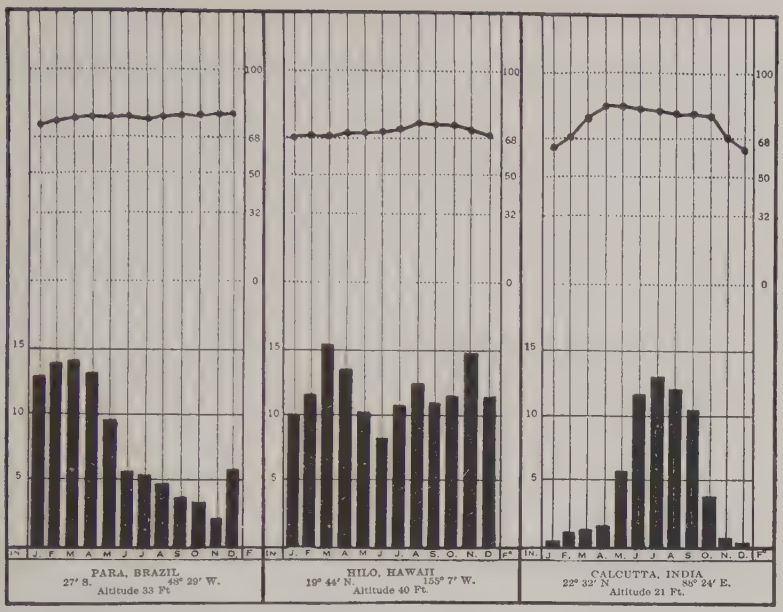


FIG. 11 FIG. 12 FIG. 13

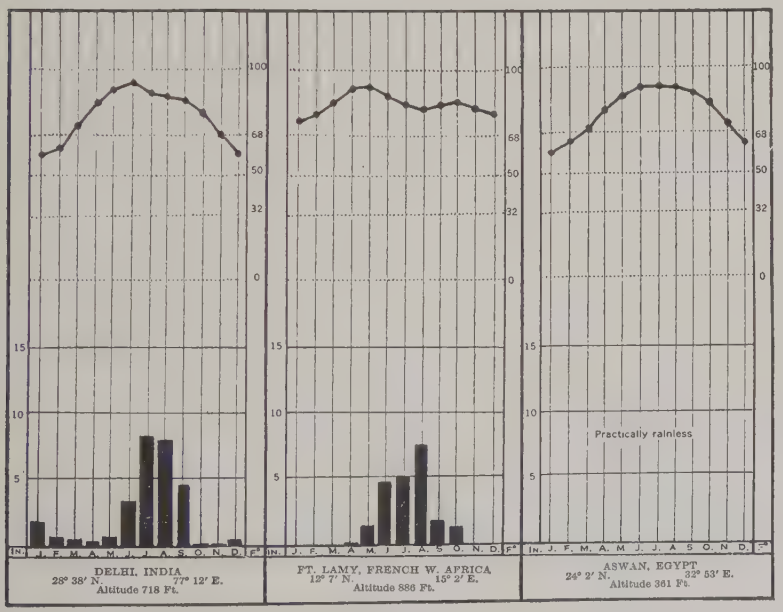


FIG. 14 FIG. 15 FIG. 16

GRAPHS OF AVERAGE MONTHLY TEMPERATURE AND RAINFALL FOR REPRESENTATIVE STATIONS

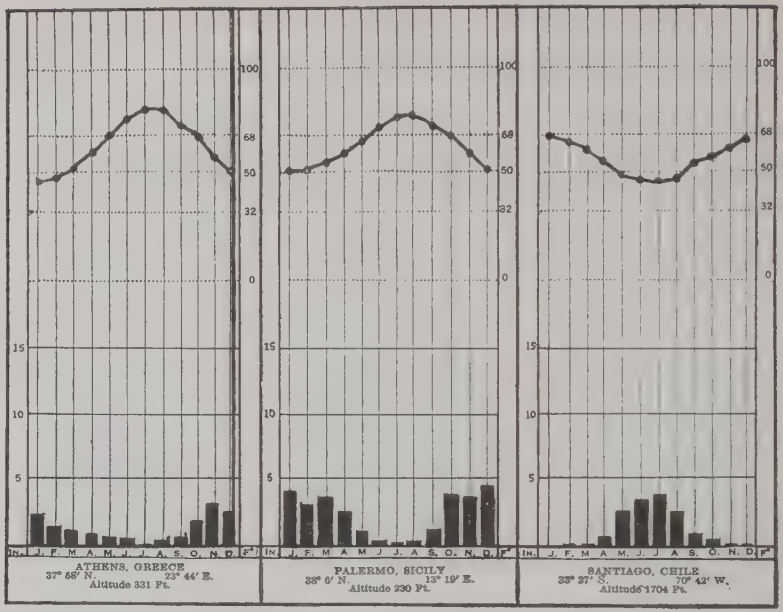


FIG. 17 FIG. 18 FIG. 19

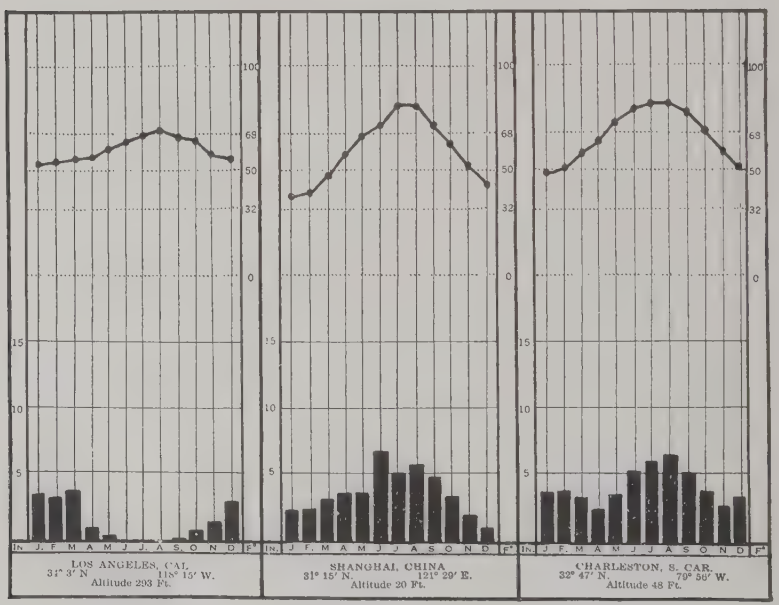


FIG. 20 FIG. 21 FIG. 22

GRAPHS OF AVERAGE MONTHLY TEMPERATURE AND RAINFALL FOR REPRESENTATIVE STATIONS

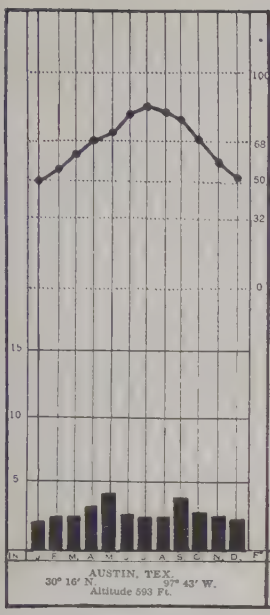


FIG. 23

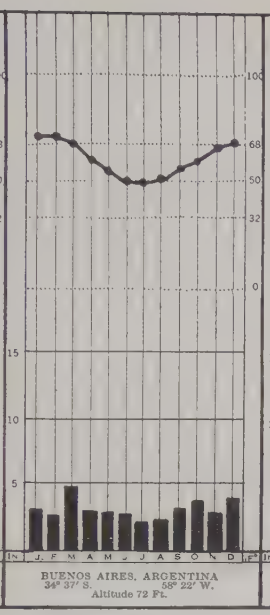


FIG. 24

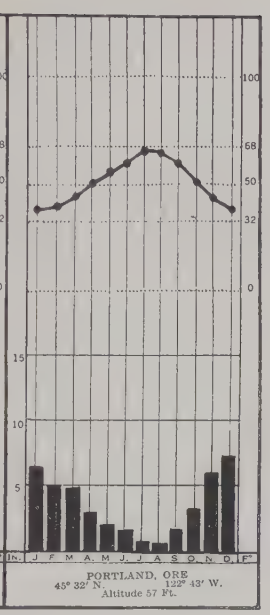


FIG. 25

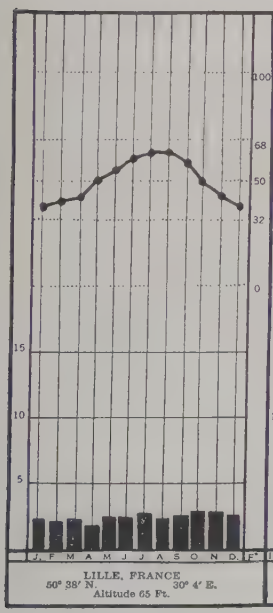


FIG. 26

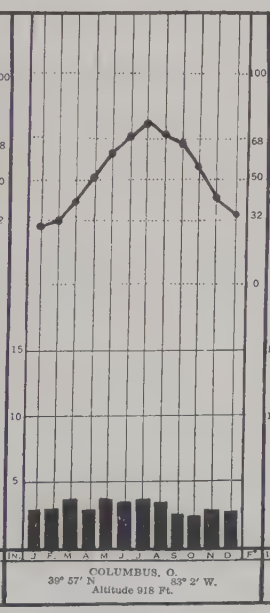


FIG. 27

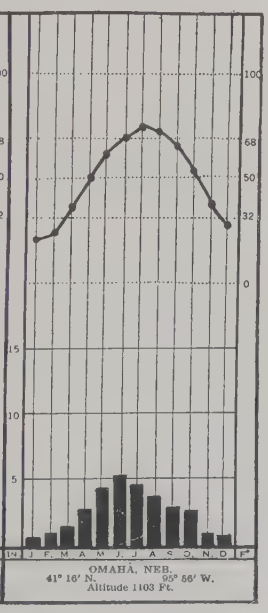


FIG. 28

GRAPHS OF AVERAGE MONTHLY TEMPERATURE AND RAINFALL FOR REPRESENTATIVE STATIONS

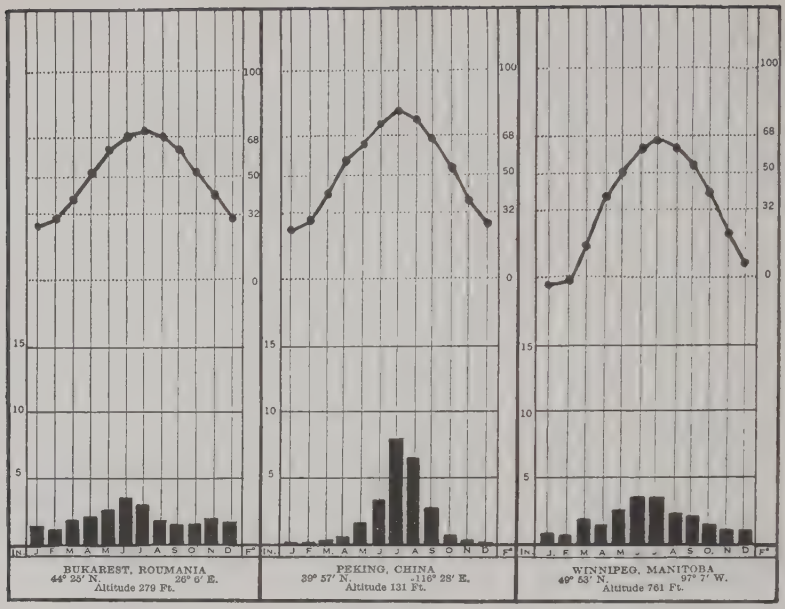


FIG. 29 FIG. 30 FIG. 31

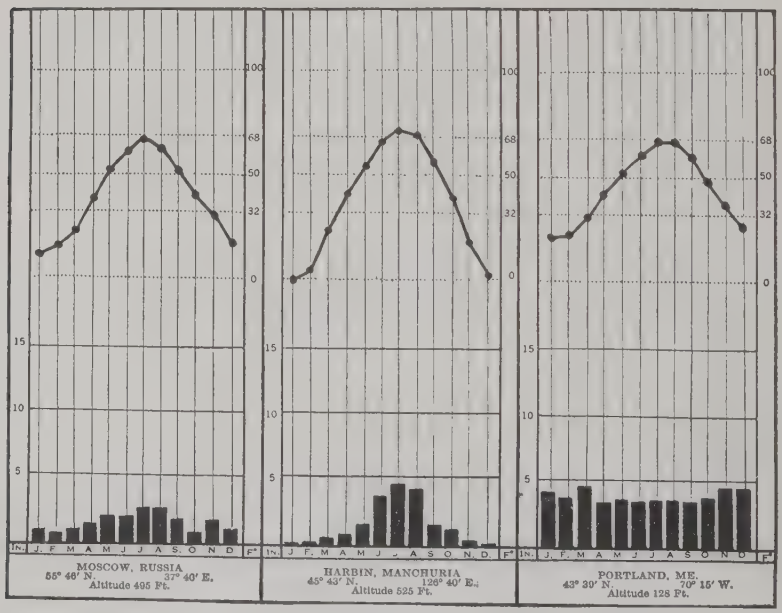


FIG. 32 FIG. 33 FIG. 34

GRAPHS OF AVERAGE MONTHLY TEMPERATURE AND RAINFALL FOR REPRESENTATIVE STATIONS

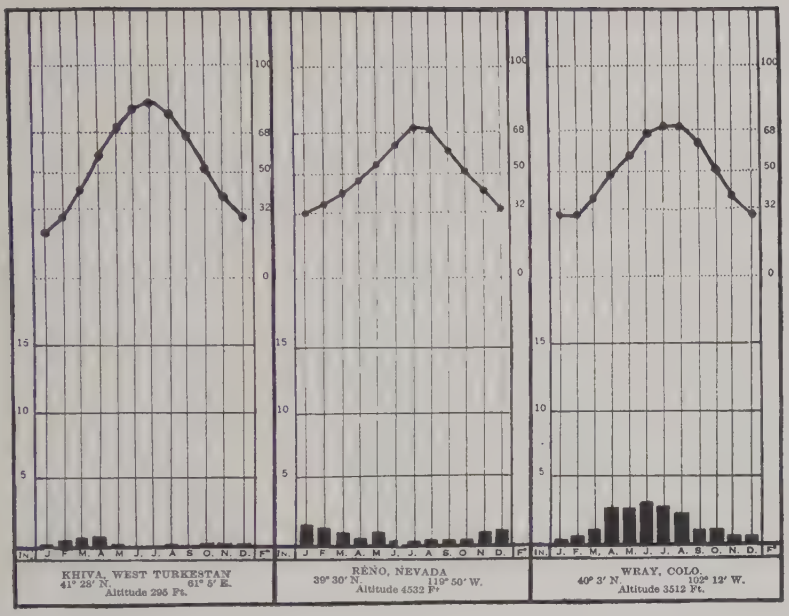


FIG. 35 FIG. 36 FIG. 37

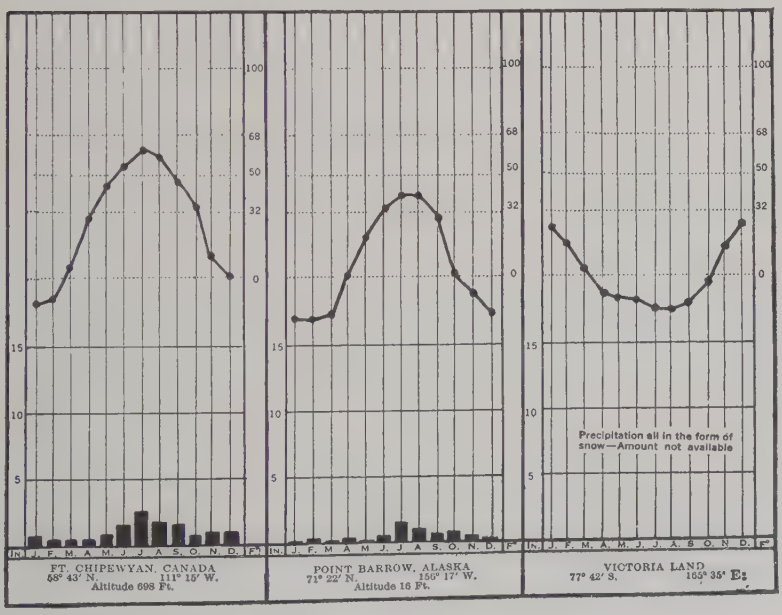


FIG. 38 FIG. 39 FIG. 40

GRAPHS OF AVERAGE MONTHLY TEMPERATURE AND RAINFALL FOR REPRESENTATIVE STATIONS

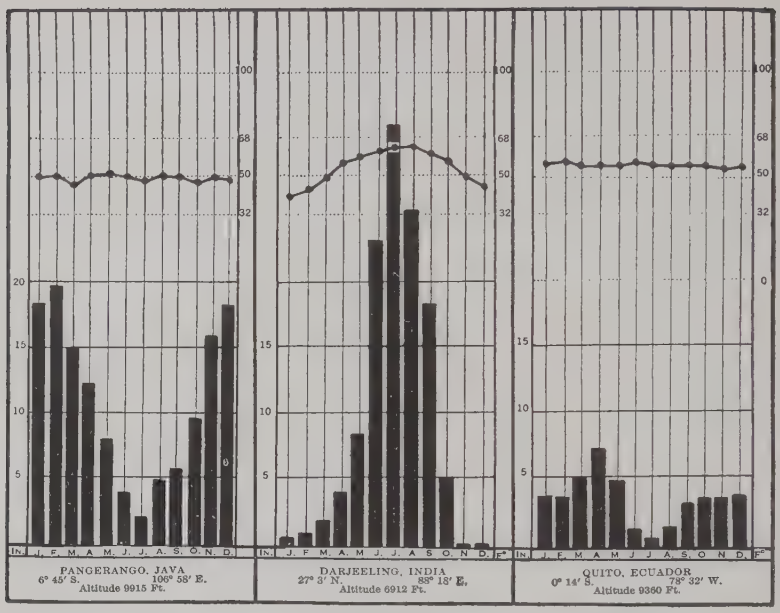


FIG. 41 FIG. 42 FIG. 43

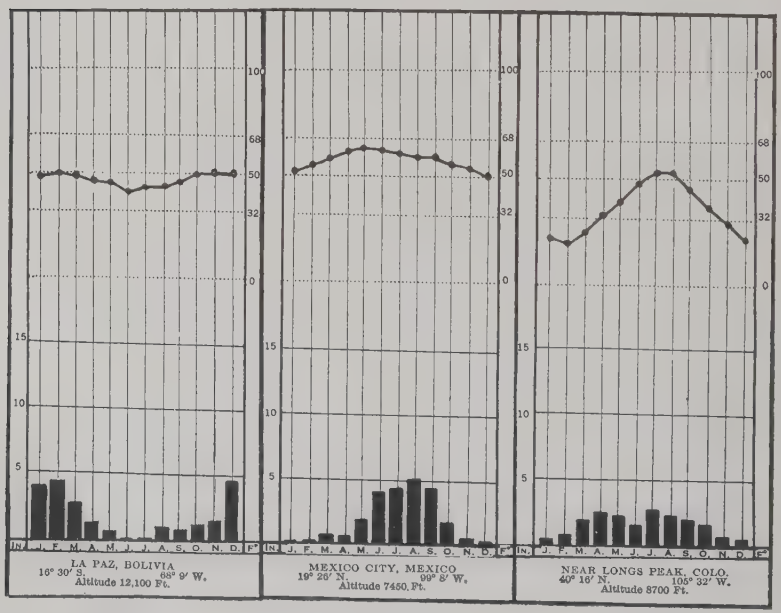


FIG. 44 FIG. 45 FIG. 46

GRAPHS OF AVERAGE MONTHLY TEMPERATURE AND RAINFALL FOR REPRESENTATIVE STATIONS

FIG. 47

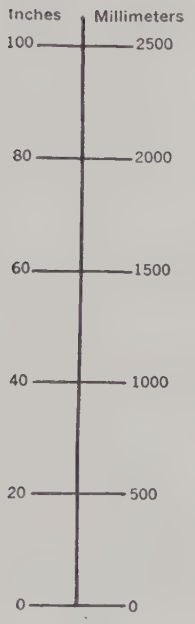


FIG. 48

FIG. 47.—Diagram illustrating the relation between Fahrenheit and Centigrade temperature scales. To change Fahrenheit into Centigrade subtract 32 and multiply by $\frac{5}{9}$. To change Centigrade into Fahrenheit multiply by $\frac{9}{5}$ and add 32.

FIG. 48.—Diagram illustrating the relation between inch and millimeter linear scales, both of which are commonly used to measure rainfall. To change inches to millimeters multiply by 25; to change millimeters to inches multiply by $\frac{1}{25}$. 10 millimeters (mm.) = 1 centimeter (cm.). Note that the diagram is not drawn to scale.

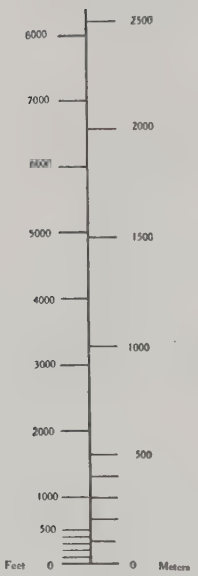


FIG. 49

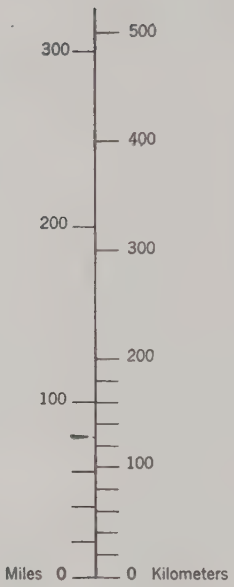


FIG. 50

FIG. 49.—Diagram illustrating the relation between feet and meter linear scales. To change feet to meters multiply by .305; to change meters to feet multiply by 3.281. The results are approximate only. 100 millimeters (mm.) = 1 meter (m.). Note that the diagram is not drawn to scale.

FIG. 50.—Diagram illustrating the relation between mile and kilometer linear scales. To change miles to kilometers multiply by 1.61; to change kilometers to miles multiply by .62. The results are approximate only. 1000 meters (m.) = 1 kilometer (km.).

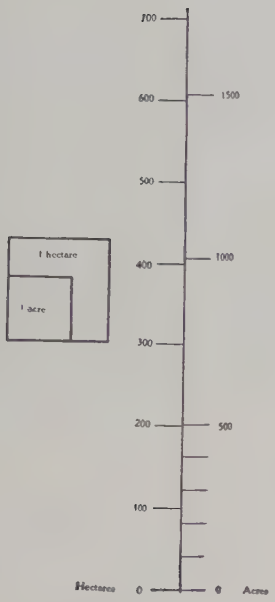


FIG. 51

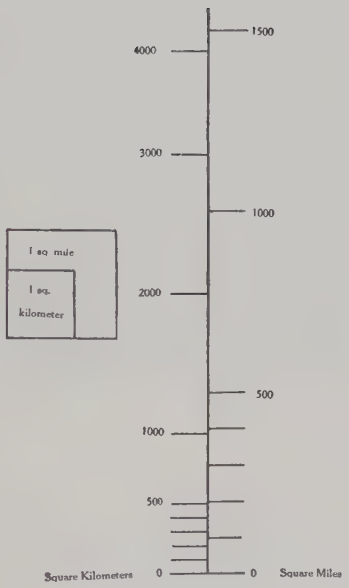


FIG. 52

FIG. 51.—Diagram illustrating the relation between acres and hectares. To change acres to hectares multiply by .405; to change hectares to acres multiply by 2.47. The results are approximate only.

FIG. 52.—Diagram illustrating the relation between square miles and square kilometers. To change square miles to square kilometers multiply by 2.07; to change square kilometers to square miles multiply by .386. The results are approximate only.

Courtesy of American Geographical Society—Isaiah Bowman

FIG. 53.—A clearing in the rainy low latitude forest of Eastern Bolivia in latitude 12° S. The rank mixed vegetation in the foreground is typical. (From the *Geographical Review*, published by the American Geographical Society of New York.)

Courtesy of Field Museum of Natural History

FIG. 54.—A native farm in a slashing in the rainy low latitude forest of the Philippines. The crops are corn, rice, and "gabi" (taro).

Courtesy of Robert S. Platt

FIG. 55.—Rude thatched house on a native farm in the rainy low latitude forest of eastern Trinidad. The crude clearing in the forest, the mixture of crops—plantains, cassava, and the like—stuck into untilled ground, the hut on posts and heavily thatched, with an open working space sheltered from sun and rain, the lack of all civilized conveniences, and the absence of a road to the outside world—all are characteristic.

Courtesy of W. H. Haas

FIG. 56.—Balls of crude rubber on the dock at Pará, Brazil

Underwood & Underwood

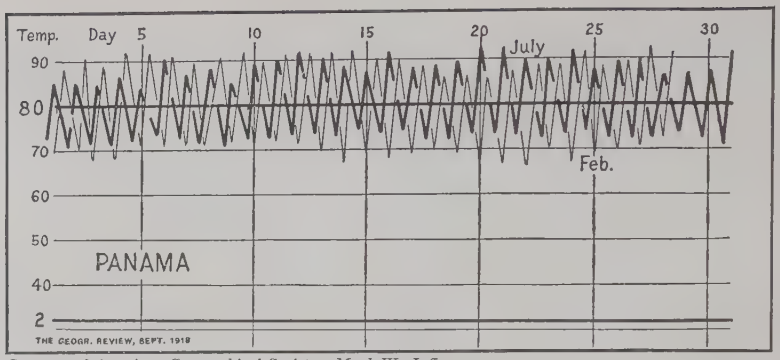
FIG. 57.—Picking cacao on a plantation in Costa Rica

Courtesy of United States Department of Commerce

FIG. 58.—Native village on stilts on a rainy low latitude coast, Celebes. The trees are coco palms. Note the steep pitch of the roofs.

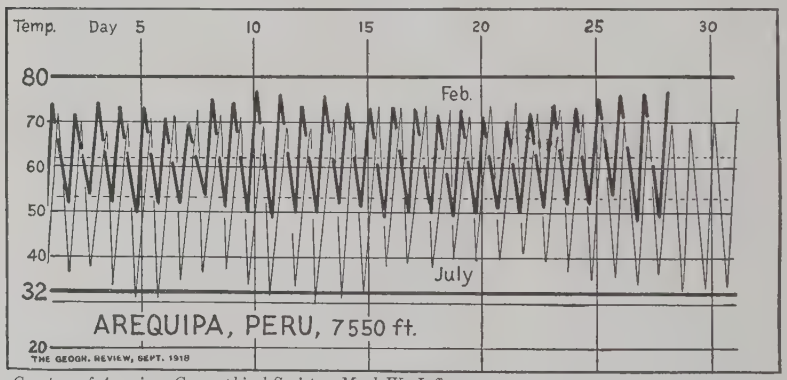
Courtesy of United Fruit Company

FIG. 59.—Picking plantation bananas. Eastern lowlands of Costa Rica



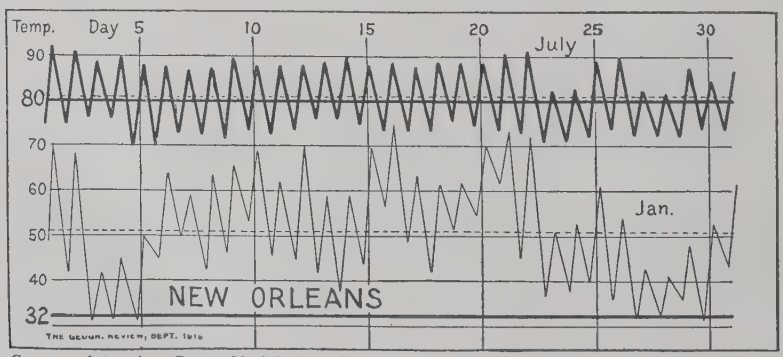
Courtesy of American Geographical Society—Mark W. Jefferson

FIG. 60. -Daily maximum and minimum temperatures for the coldest and the warmest months of 1913 in Panama City, Panama. (This and the five graphs following are from the *Geographical Review*, published by the American Geographical Society of New York.)



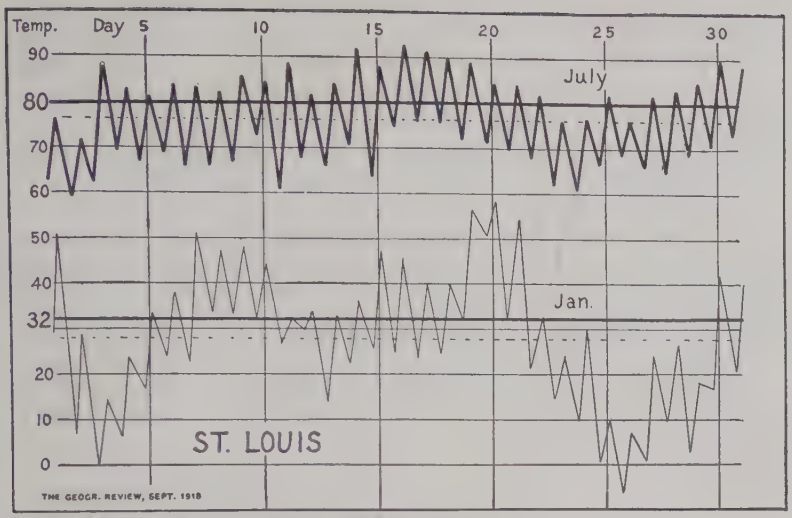
Courtesy of American Geographical Society—Mark W. Jefferson

FIG. 61.—Daily maximum and minimum temperatures for the coldest and the warmest months of 1889 in Arequipa, Peru, 7,550 feet above sea-level.



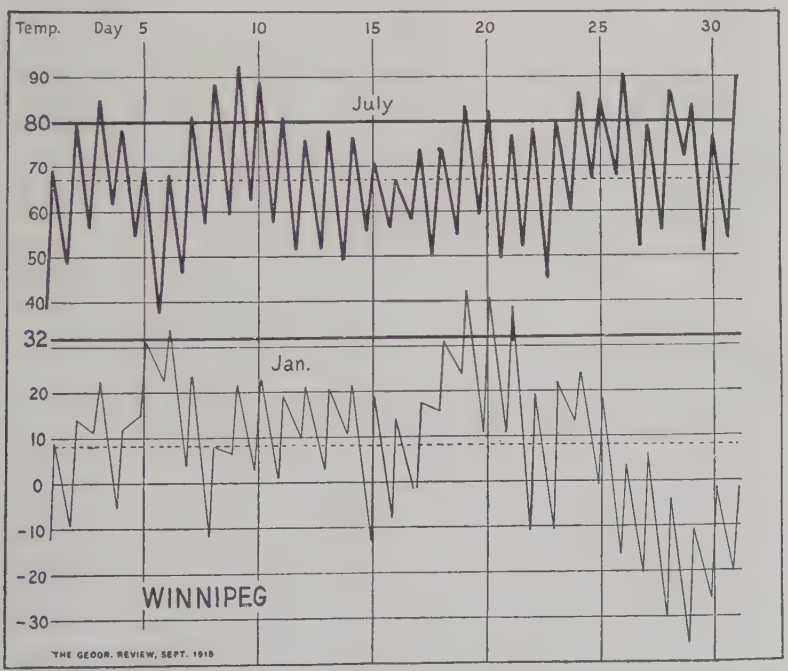
Courtesy of American Geographical Society—Mark W. Jefferson

FIG. 62.—Daily maximum and minimum temperatures for the coldest and the warmest months of 1904 in New Orleans, Louisiana.



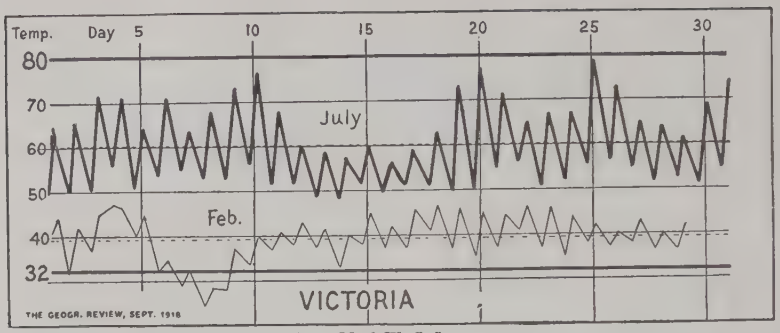
Courtesy of American Geographical Society—Mark W. Jefferson

FIG. 63.—Daily maximum and minimum temperatures for the coldest and the warmest months of 1904 in St. Louis, Missouri.



Courtesy of American Geographical Society—Mark W. Jefferson

FIG. 64.—Daily maximum and minimum temperatures for the coldest and the warmest months of 1908 in Winnipeg, Manitoba.



Courtesy of American Geographical Society—Mark W. Jefferson

FIG. 65.—Daily maximum and minimum temperatures for the coldest and the warmest months of 1904 in Victoria, British Columbia.

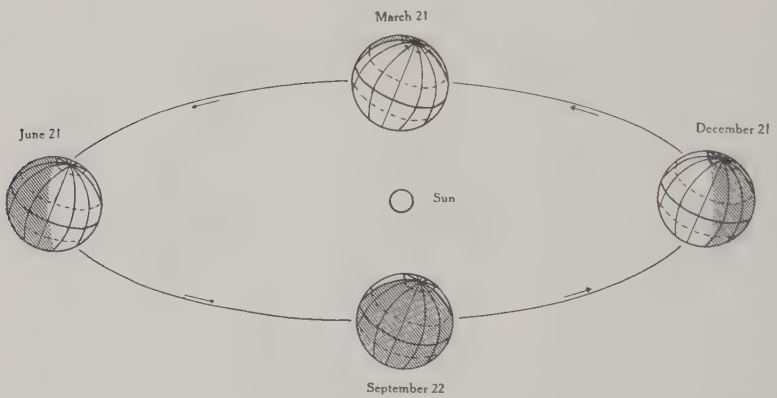


FIG. 66.—Diagram illustrating the annual revolution of the earth about the sun. The arrows indicate the direction in which the earth revolves; the four positions of the earth shown are those of the two equinoxes and the two solstices. Relatively the earth is much smaller and its distance from the sun much greater than the diagram indicates. The orbit of revolution is in fact almost a circle; in this diagram the view is oblique to the plane of the orbit of revolution. At all times half the earth is light and half is dark, the line separating the two halves being called the "circle of illumination." Note where the circle of illumination cuts the several parallels of latitude at the different seasons, and estimate the relative length of day and night at points on these parallels. If the axis of the earth were perpendicular to the plane of its orbit of revolution, the length of day and night would be equal at all times of the year in all latitudes. The axis is inclined from the perpendicular about $23\frac{1}{2}°$.

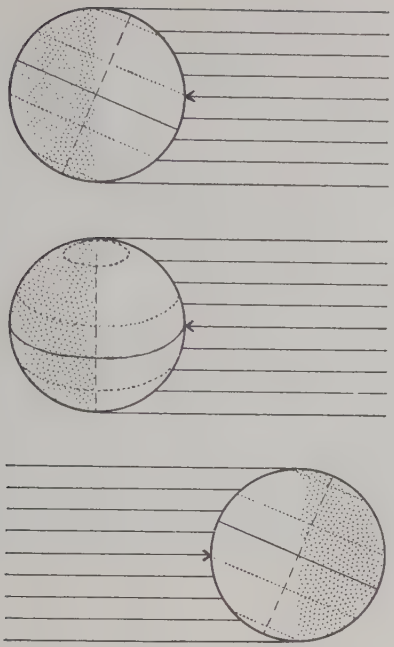


Fig. 67.—Diagrams of the earth showing variations in sun heating with the seasons and with latitude. These diagrams illustrate the positions of the earth shown in Figure 66, and should be used with that figure in studying seasonal and latitudinal variations in temperature. Note the proportion of the equator, the tropics, and the polar circles in light and the proportion in dark on different dates, and deduce the consequent relative length of day and night. Observe the angle at which the sun's rays strike the surface of the earth in these latitudes

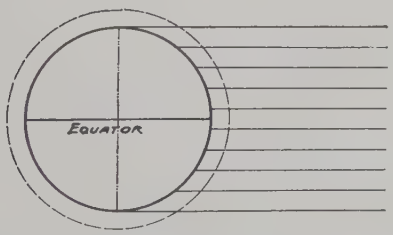


Fig. 68.—Diagram illustrating latitudinal variations in (*a*) the angle at which the sun's rays strike the earth's surface, (*b*) the distance through the atmosphere which the rays must travel to reach the earth's surface, and (*c*) the area heated by a given amount of sunlight.

Courtesy of American Geographical Society—E. F. Gautier

FIG. 69.—A section of low latitude desert devoid of vegetation—the Libyan Desert. (From the *Geographical Review*, published by the American Geographical Society of New York.)

Underwood & Underwood

FIG. 70.—An oasis in a low latitude desert. A view across the Nile Valley in Egypt, showing the unirrigated, barren uplands, the tilled and ditched valley flood-plain, threshing floors, and palms in the moist soils which fringe the stream.

W. D. J.

FIG. 71.—The scattered vegetation of a low latitude desert—the Thar, India

W. D. J.

FIG. 72.—The dry season in a teak forest of Southwestern Coastal India, south of Cochin. The largest trees have been logged off and the undergrowth is partly cleared out.

Courtesy of H. S. Kemp

FIG. 73.—Hauling mahogany in the forest of the wet-and-dry climate of Costa Rica.

Courtesy of American Geographical Society—Heller

FIG. 74.—"Park" vegetation on the East African Highland. Mount Longonot is the mountain rising in the background. (From the *Geographical Review*, published by the American Geographical Society of New York.)

Courtesy of Robert S. Platt

FIG. 75.—Typical vegetation on the Llanos, near the Orinoco River

W. D. J.

FIG. 76.—Setting out rice plants in a field near Madras, India

W. D. J.

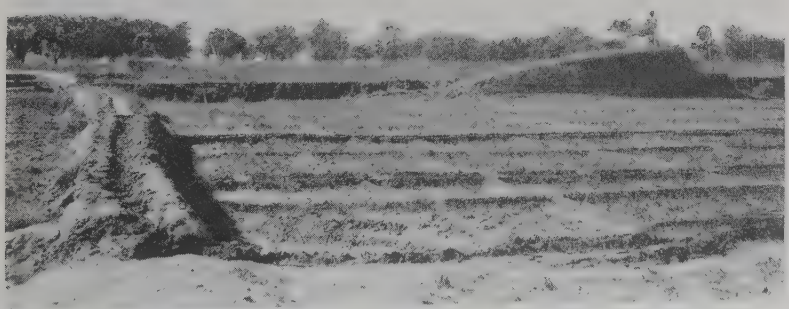
Fig. 77.—Rice field just before harvest, near Madras, India

W. D. J.

Fig. 78.—A plantation of rubber (*Hevea braziliensis*) on the Malabar Coast near Cochin, India.

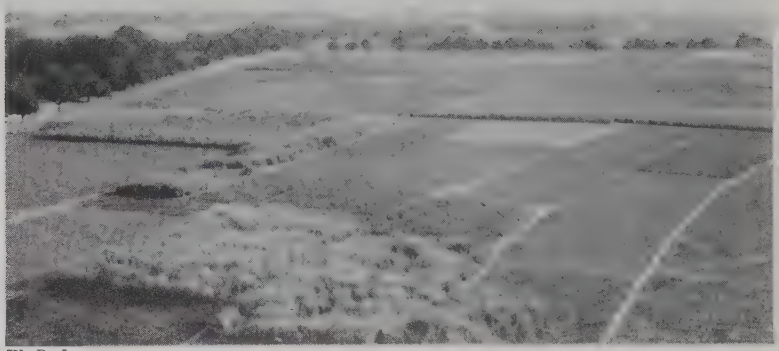
W. D. J.

FIG. 79.—A village on the Malabar Coast south of Cochin, India



W. D. J.

FIG. 80.—Irrigated crops and unirrigated mango groves side by side on the Upper Ganges Plain, near Agra.



W. D. J.

FIG. 81.—Dry season crops, irrigated from wells, on a well-drained alluvial plain near Benares, India. The crops are wheat, oil seeds, and sugar cane.

W. D J.

FIG. 82.—Grain sorghum near Nagpur, India

W. D. J.

FIG. 83.—A river of the wet-and-dry low latitude climate during the dry season. A few miles east of Poona, Bombay Presidency, India. During the rains the stream fills the channel.

W. D. J.

FIG. 84.—Salt-making, on Sambhar Lake, Rajputana, India. This occupation is characteristic of inland lakes as well as of seacoasts in all low latitude types of climate which have a dry season.

Courtesy of Robert S. Platt

FIG. 85.—Cutting sugar cane on a plantation in Guadeloupe, West Indies

Courtesy of Robert S. Platt

FIG. 86.—Deciduous trees in a pineapple plantation in Western Cuba

Courtesy of American Geographical Society—Heller

FIG. 87.—Native flora, fauna, and inhabitants of Kenya Colony, East Africa. (From the *Geographical Review*, published by the American Geographical Society of New York.)

Courtesy of W. J. G. Land

FIG. 88.—Irrigation agriculture on a piedmont plain on the Mexican Plateau. Snow-capped Mount Ixtacchihuatl in the background.

Courtesy of Smithsonian Institution

FIG. 89.—Young coffee plants among felled trees on highlands, Alta Vera Paz, Guatemala.

W. D. J.

FIG. 90.—Tea plantations on slopes in the upland of Central Ceylon

W. D. J.

FIG. 91.—Apples from the Kashmir Basin, ready for shipment to the lowlands of India. Srinagar, Kashmir. Elevation of the basin 5,000–6,000 feet.

W. D. J.

FIG. 92.—The wool market in Srinagar, Kashmir. Wool brought down from Tibet by pack train is here transferred to caravans of carts which carry it to the lowlands of Northern India.

W. D. J.

FIG. 93.—Hand sawing in a timber yard of the eastern Himalayas

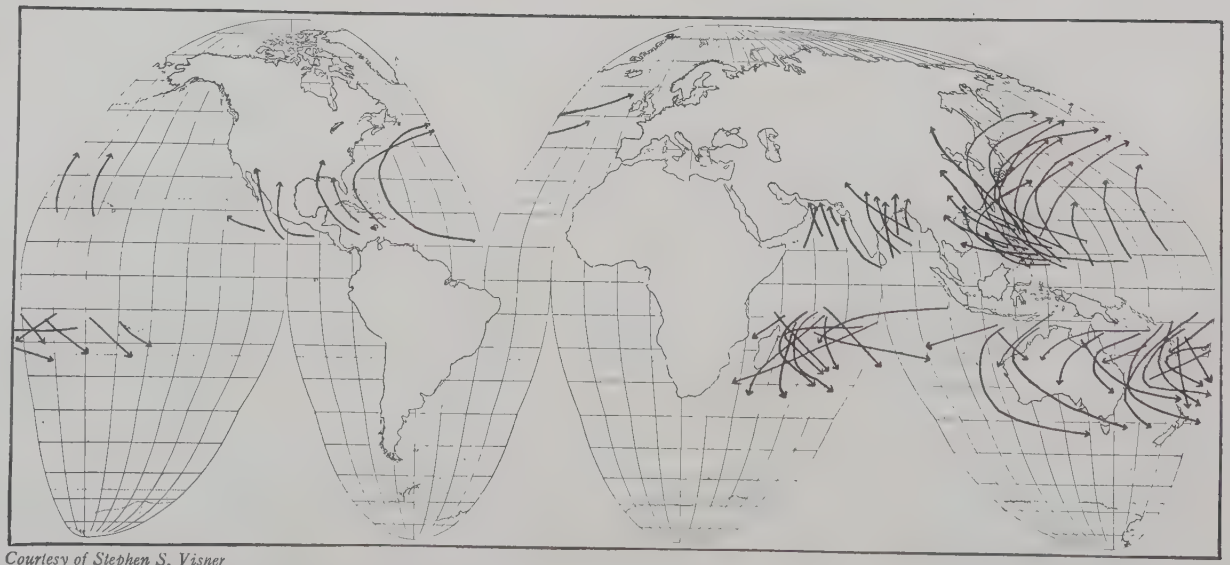
W. D. J.

FIG. 94.—Tea under slats in a clearing in the lowland forest a few score miles south of Darjeeling, India.

W. D. J.

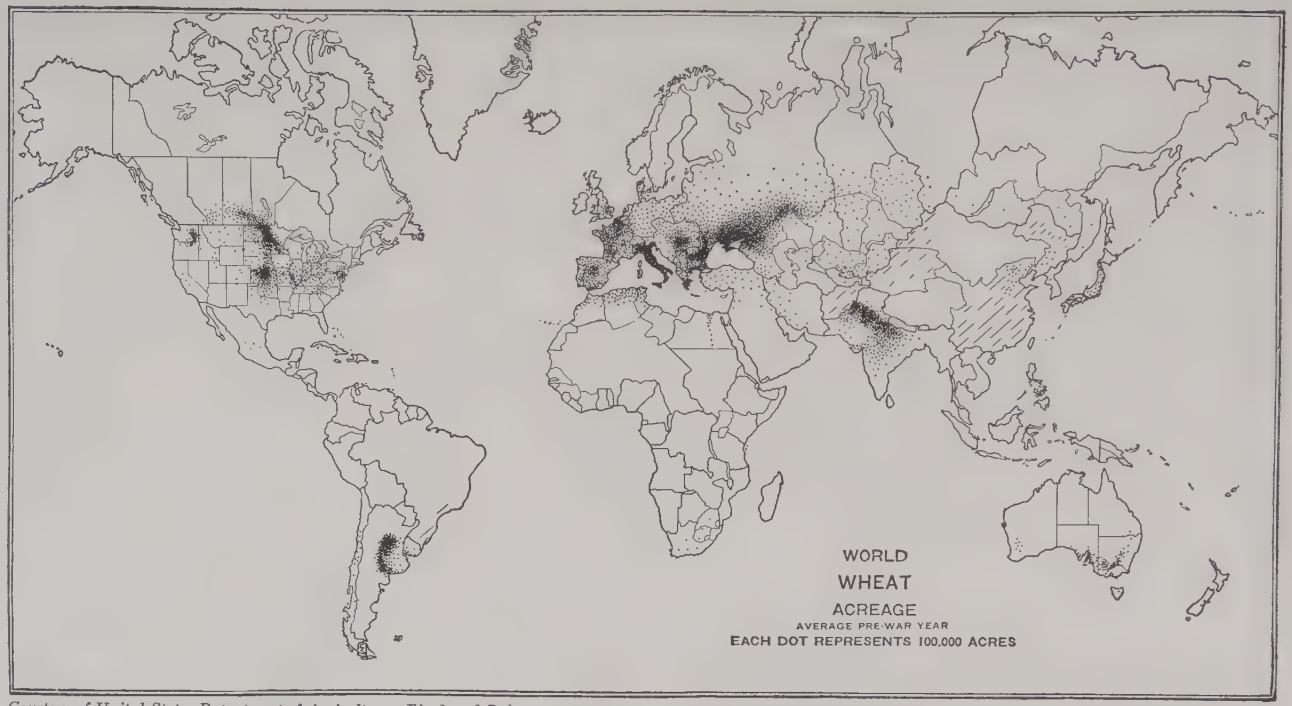
FIG. 95.—An Anglo-Indian bungalow on the plains of the Punjab, India. The thick roof, high attic, wide eaves, and large and numerous openings are designed to afford maximum coolness.

FIG. 96.—Darjeeling, a hill station of Northern India, elevation about 6,900 feet. The snowy range of the Himalayas, with Mount Everest, in the distance.



Courtesy of Stephen S. Visner

FIG. 97.—World-map of tropical cyclones (including typhoons and hurricanes). For each region the tracks shown are typical, and their number is the annual average.

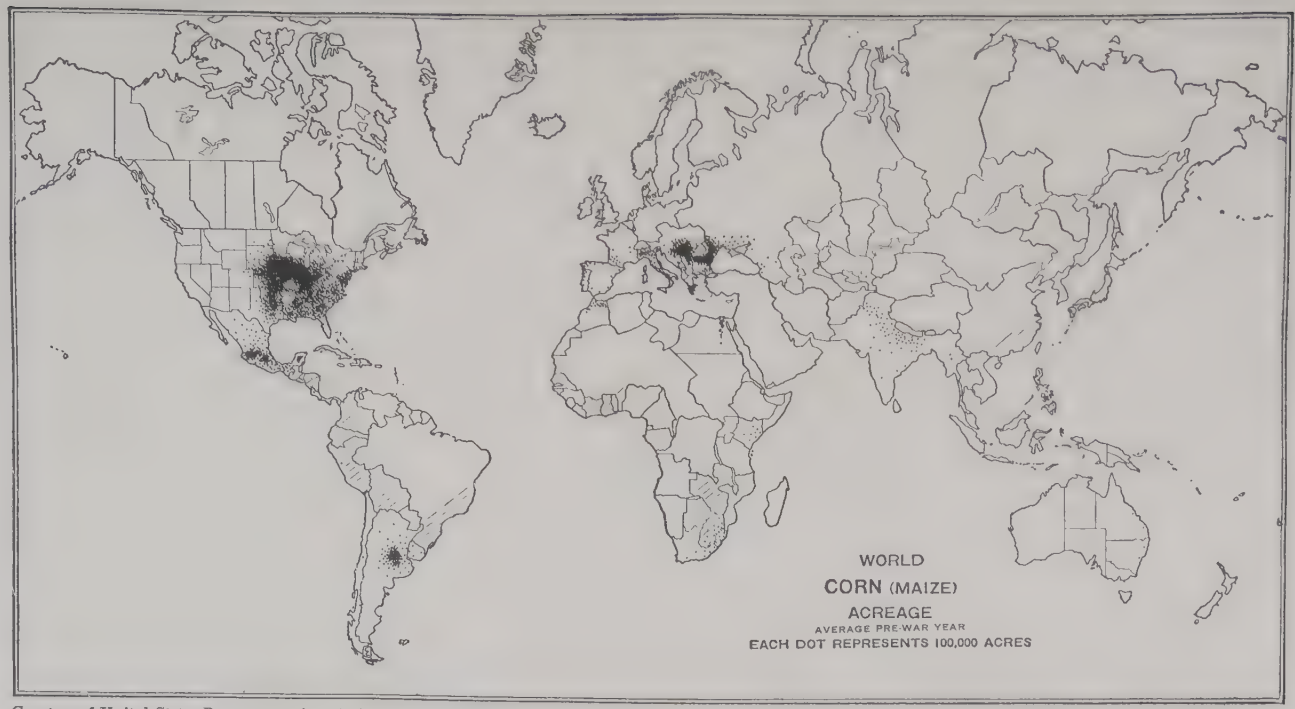


Courtesy of United States Department of Agriculture—Finch and Baker FIG. 98

NOTE.—This and several maps which follow are reprinted from Finch and Baker, *Geography of World Agriculture.* Washington: Department of Agriculture, 1917.

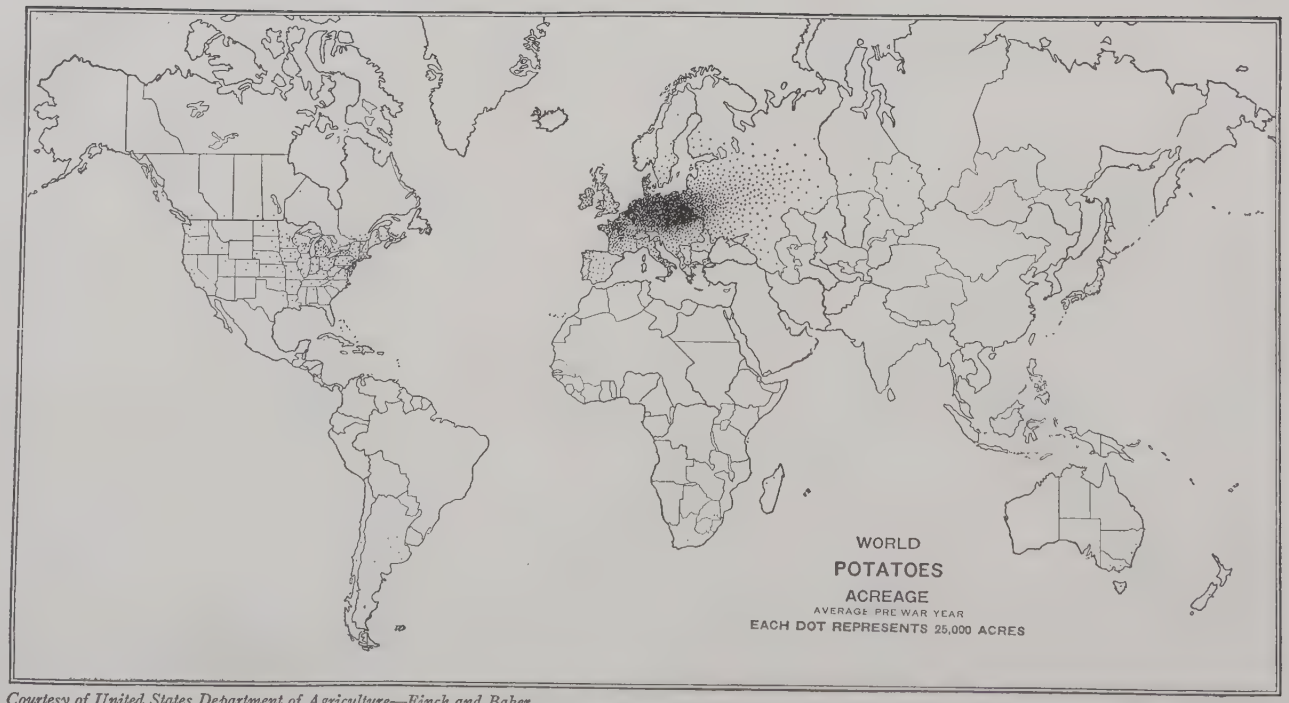
Courtesy of United States Department of Agriculture—Finch and Baker

FIG. 99



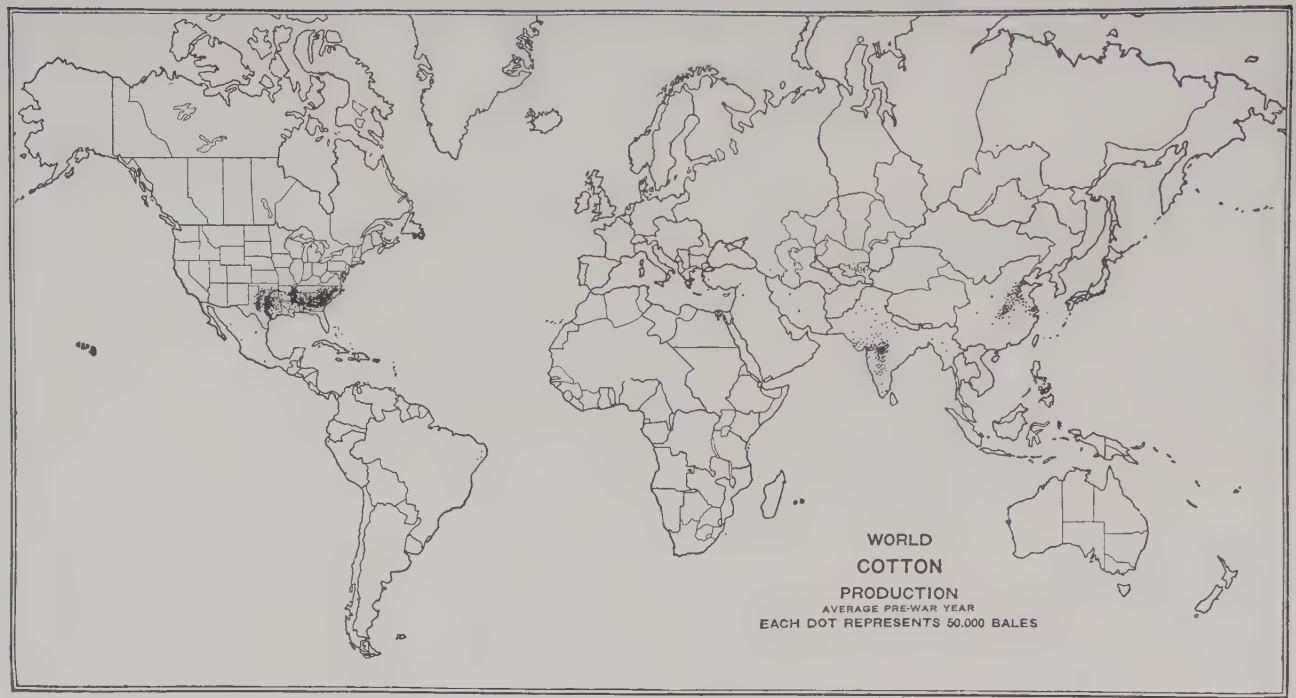
Courtesy of United States Department of Agriculture—Finch and Baker

FIG. 100



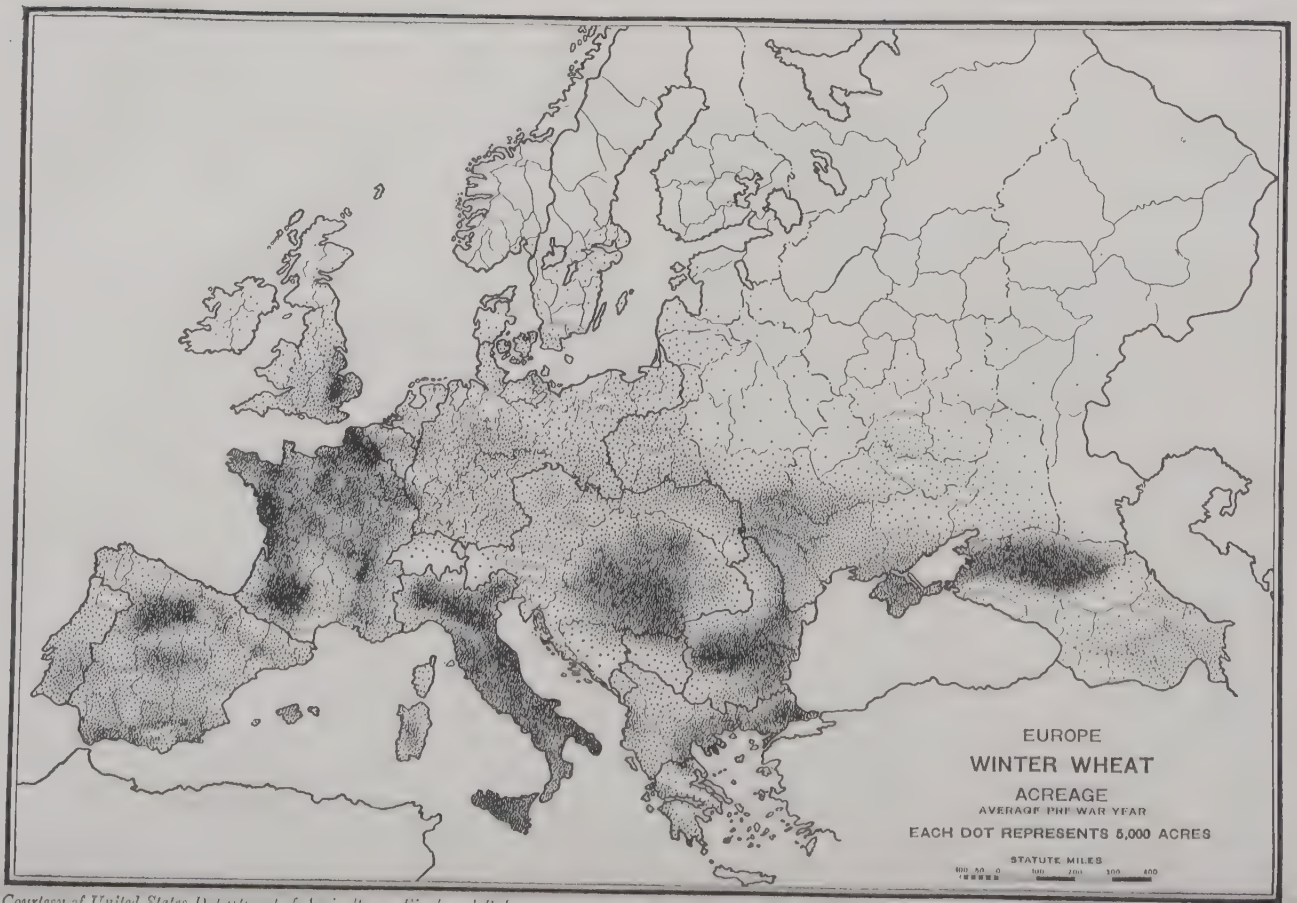
Courtesy of United States Department of Agriculture—Finch and Baker

FIG. 101



Courtesy of United States Department of Agriculture—Finch and Baker

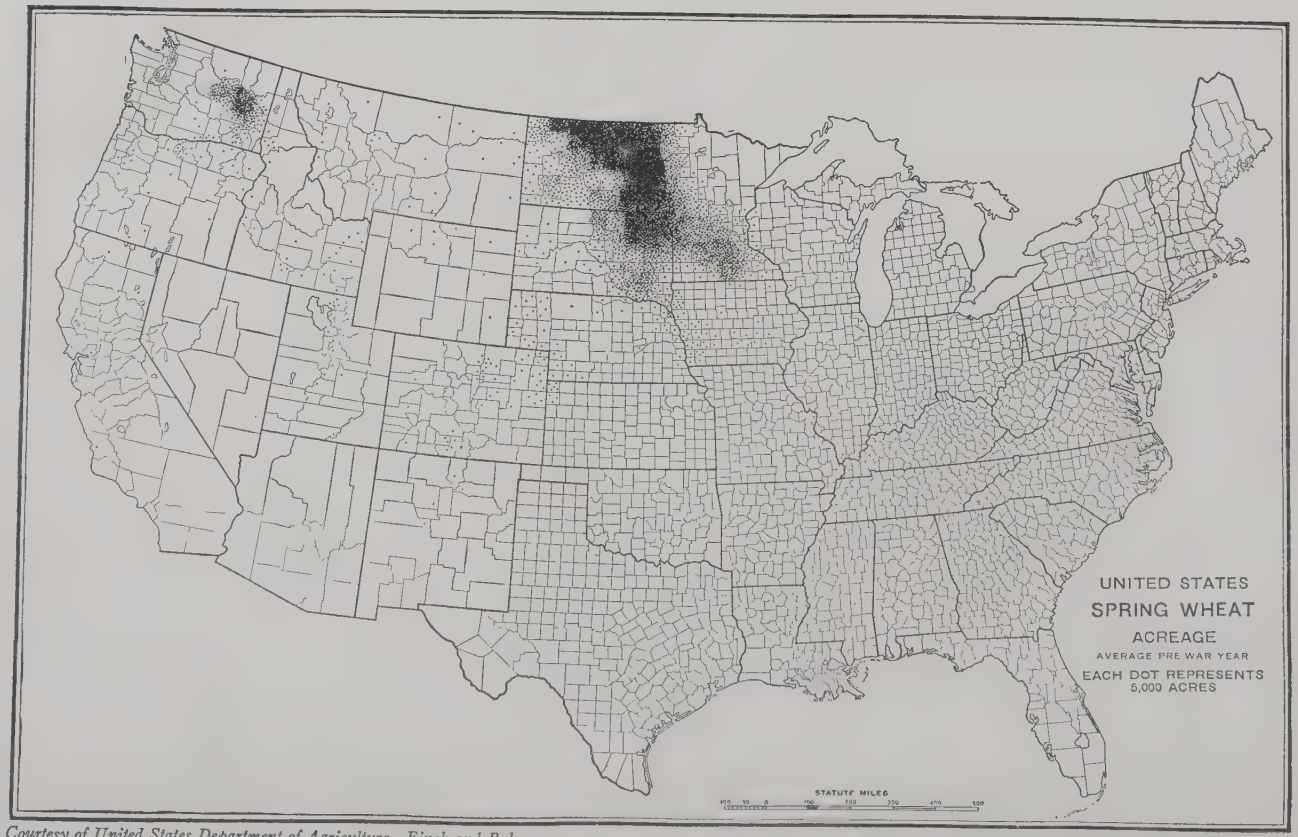
FIG. 102



Courtesy of United States

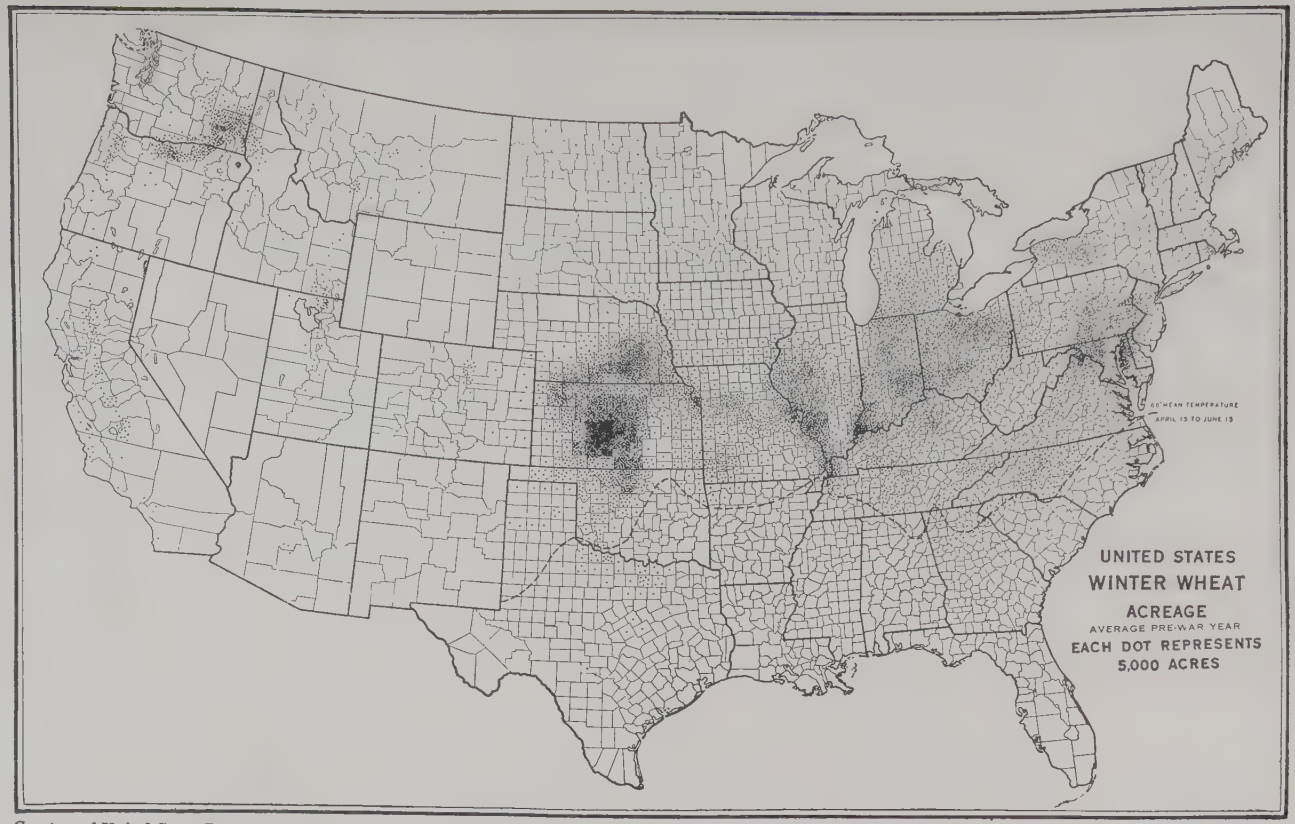
Courtesy of United States Department of Agriculture—Finch and Baker

FIG. 104



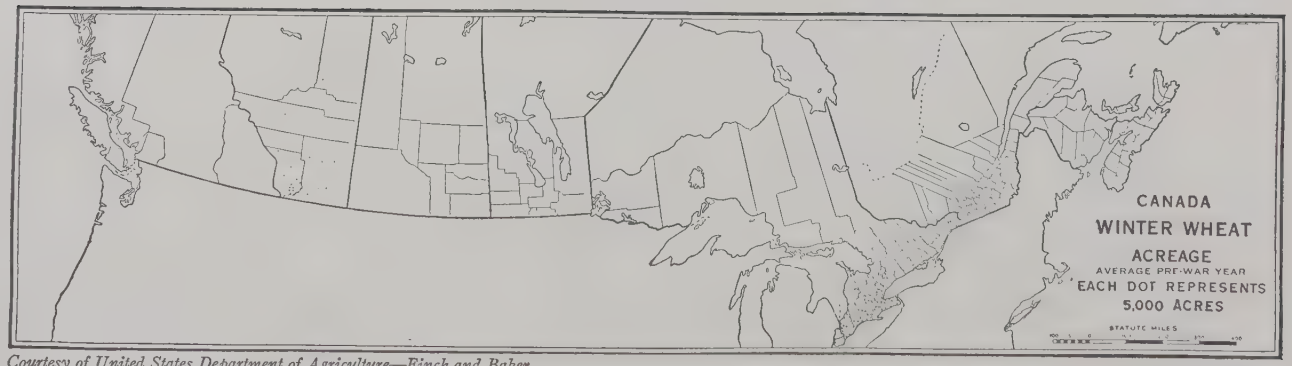
Courtesy of United States Department of Agriculture—Finch and Baker

FIG. 105



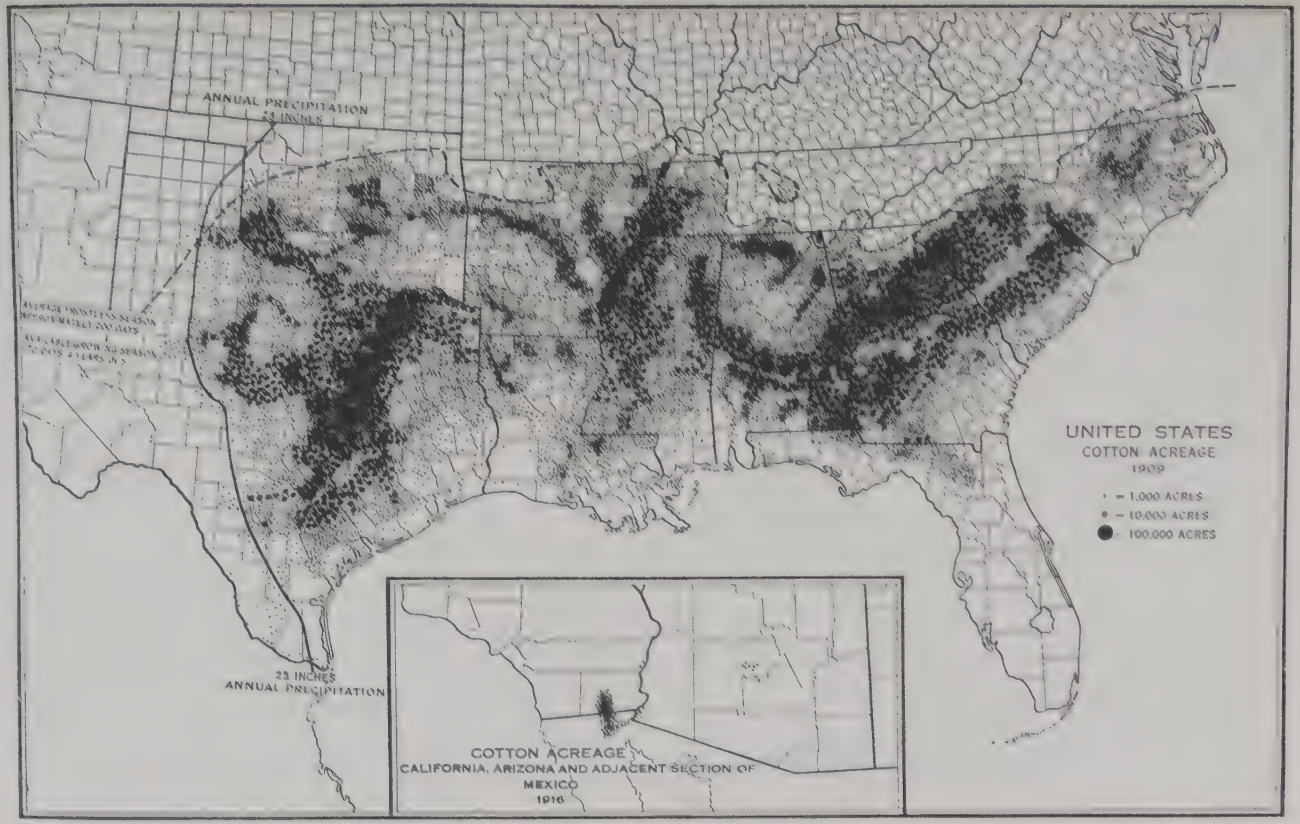
Courtesy of United States Department of Agriculture—Finch and Baker

FIG. 106



Courtesy of United States Department of Agriculture—Finch and Baker

FIG. 107



Courtesy of United States Department of Agriculture—Atlas of American Agriculture

FIG. 108

Fred. Boissonnas

FIG. 109.—Typical vegetation of the Mediterranean climate—Southern Greece. Olives in the foreground, cypress in the middle distance, and chaparral on the mountain.

Fred. Boissonnas

FIG. 110.—Harvesting the olive crop, Southern Greece

Keystone View

FIG. 111.—Irrigated orange grove in Southern California

Courtesy of American Geographical Society—F. E. Dean

FIG. 112.—Heaters in an irrigated orchard near Grand Junction, Colorado. Similar methods are employed in Southern California and in many other fruit districts. (From the *Geographical Review*, published by the American Geographical Society of New York.)

W. D. J.

FIG. 113.—Irrigated rice fields on a floodplain, southern Hunan Province, China.

Underwood & Underwood

FIG. 114.—A cotton field in Georgia

Keystone View

FIG. 115.—Tea on hill slopes, rice on lowlands, near Shidzuoka, Japan, southwest of Yokohama.

W. D. J.

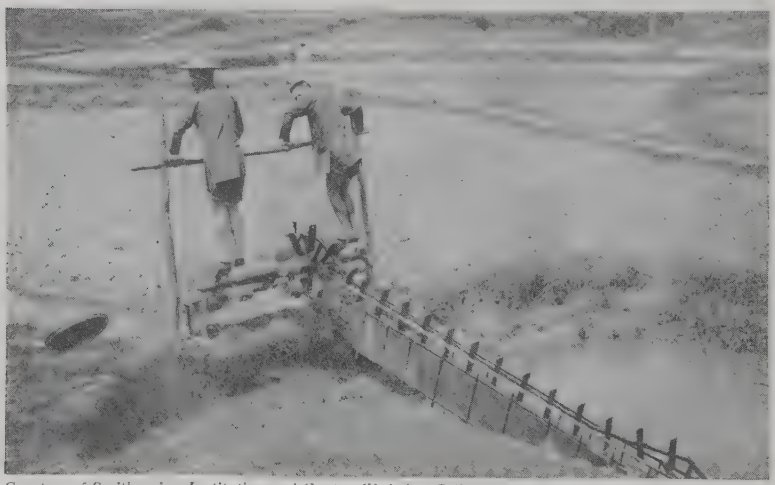
FIG. 116.—A method of drying and curing rice in spite of rain-soaked fields. Near Kyoto, Japan.

Courtesy of R. T. Chamberlin

FIG. 117.—Harvested rice hung in trees to dry. West Central China, some 250 miles east of Chengtu, Szechuan Province. The sodden fields and the high atmospheric humidity make it impossible to prepare the crop for threshing by ordinary shocking or stacking.

W. D. J.

FIG. 118.—Drying rice grains in the damp climate of Central China, southern Hunan Province. The grain is spread out on a bamboo mat almost every sunny day between the time it is threshed and the time it is eaten.



Courtesy of Smithsonian Institution and Canton Christian College

FIG. 119.—Lifting water on to a rice field, near Canton, China

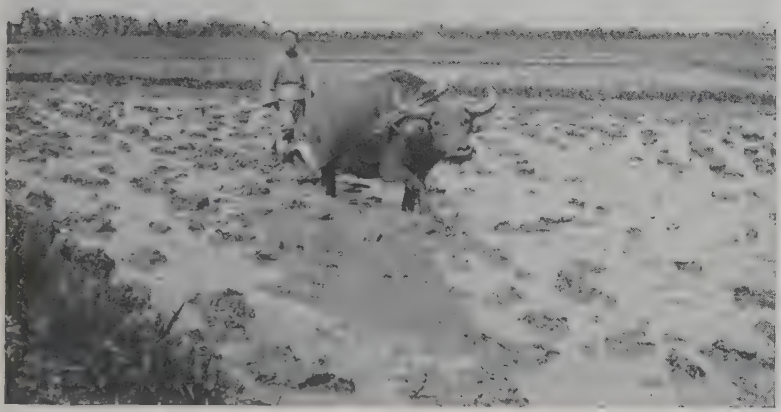


FIG. 120.—Water buffalo plowing a rice field in Central China

W. D. J.

FIG. 121.—Low water in the Siang River, Hunan Province, China

W. D. J.

FIG. 122.—A clearing in luxuriant forest on the shore of Lago Nahuel Huapi, in the mild-winter–mild-summer climate of the Southern Andes, latitude 41° S.

Courtesy of United States Geological Survey and Curtis, Seattle

FIG. 123*a*.—Forest in Western Washington, characteristic of the mild-winter–mild-summer type of climate.

Cress, Seattle

FIG. 123*b*.—Logging in the dense forest of the Pacific Northwest

Lawrence Photo, Dublin, Copyright

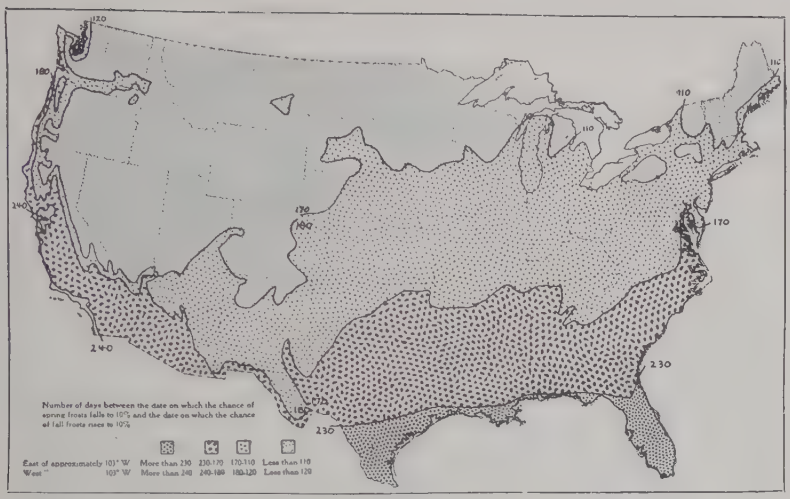
FIG. 124.—Dairy herd and luxuriant pastures of Western Ireland

Courtesy of International Harvester Co.

FIG. 125.—Shocks in a wheat field of the Red River Valley

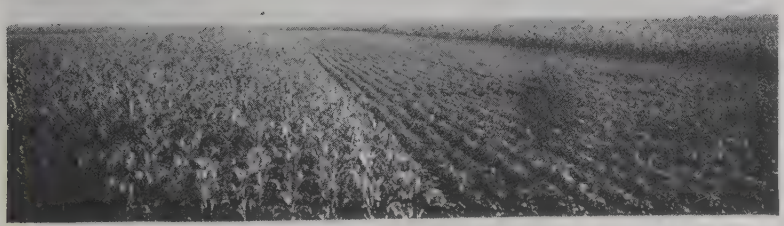
Courtesy of United States Department of Agriculture

FIG. 126.—"Hogging down" corn, in the Corn Belt of North Central United States.


120
180
240
170
100
110
110
110
170
240
230
175
150
230
Number of days between the date on which the chance of spring frosts falls to 10% and the date on which the chance of fall frosts rises to 10%
East of approximately 103° W More than 230 230-170 170-110 Less than 110
West " 103° W More than 240 240-180 180-120 Less than 120

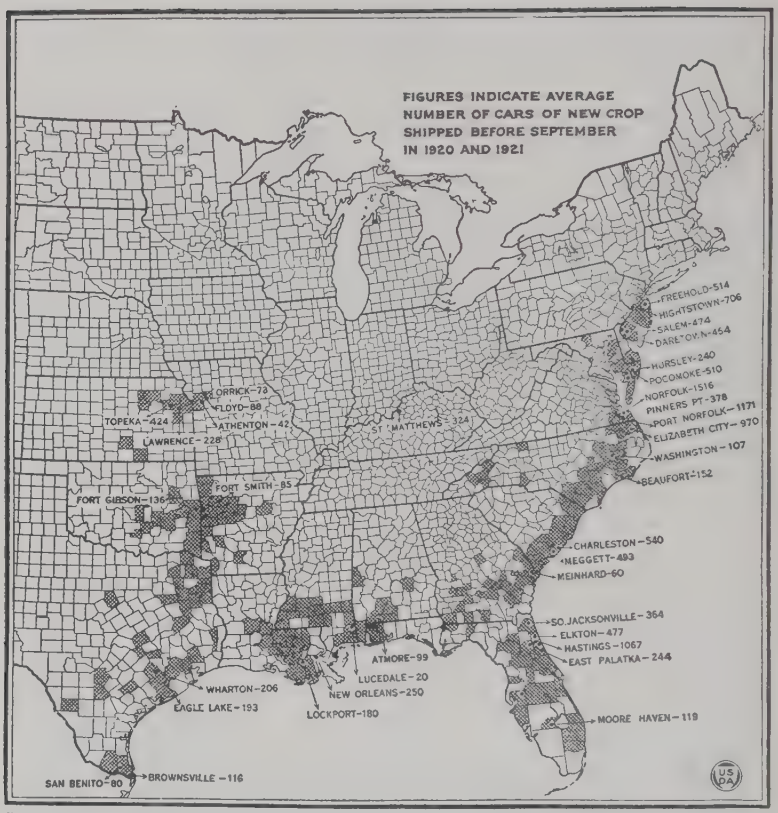
Courtesy of United States Department of Agriculture—Atlas of American Agriculture

FIG. 127.—The season available for the growth of crops in four-fifths of the years.



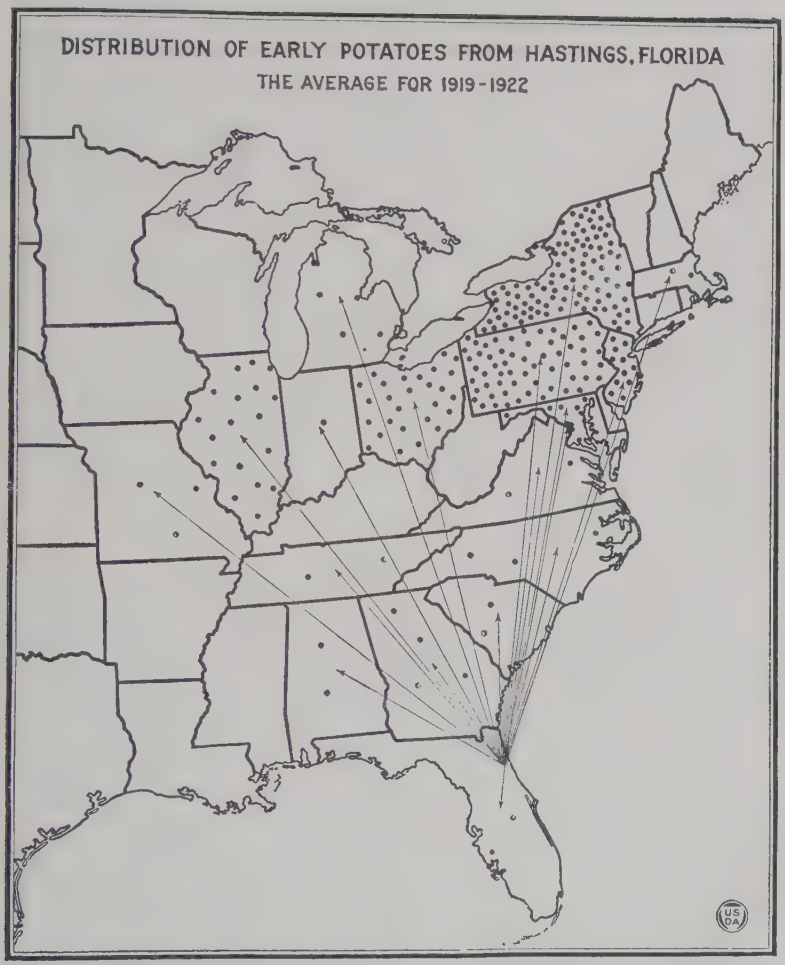
W. D. J.

FIG. 128.—A cultivated plain in the humid continental climate with long summers near Mukden, Manchuria. The crops are kaoliang (a grain sorghum) and beans.



Courtesy of United States Department of Agriculture

FIG. 129.—Counties in Southeastern United States which lead in shipments of early potatoes, and principal shipping stations.



Courtesy of United States Department of Agriculture

FIG. 130.—Hastings is one of the largest potato-shipping stations in the United States (see Fig. 129). Each dot on this map represents 10 cars of potatoes sent from Hastings. Most of the shipments were to the larger cities; thus nearly all the potatoes sent to Michigan were shipped to Detroit.

FIG. 131.—Winter landscape in Chicago

FIG. 132.—Summer landscape in Chicago

Courtesy of Michigan Central Railroad

FIG. 133.—Snow plow on the Michigan Central Railroad in Northern Michigan

Courtesy of Swift & Co.

FIG. 134.—Cutting ice on Lake Calumet, Chicago

Courtesy of United States Weather Bureau

FIG. 135.—A tornado cloud at Solomon, Kansas

Courtesy of American Geographical Society—J. F. Carey

FIG. 136.—Destruction wrought by a tornado at Charleston, Illinois. (From the *Geographical Review*, published by the American Geographical Society of New York.)

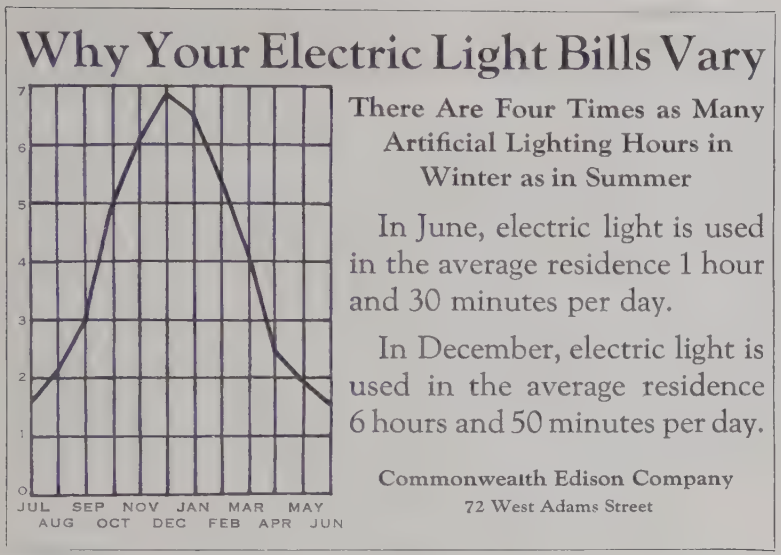
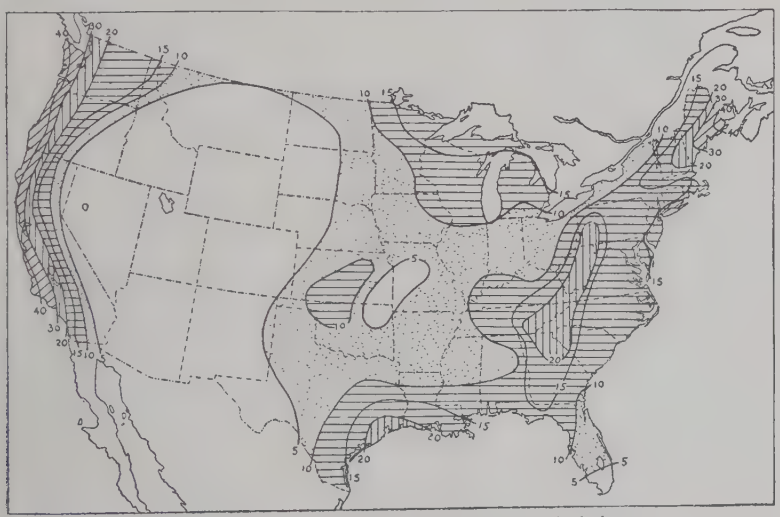

Why Your Electric Light Bills Vary
There Are Four Times as Many Artificial Lighting Hours in Winter as in Summer
In June, electric light is used in the average residence 1 hour and 30 minutes per day.
In December, electric light is used in the average residence 6 hours and 50 minutes per day.
Commonwealth Edison Company
72 West Adams Street
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN

FIG. 137.—The number of hours artificial light is used daily in Chicago, by months.



Courtesy of United States Department of Agriculture—Atlas of American Agriculture

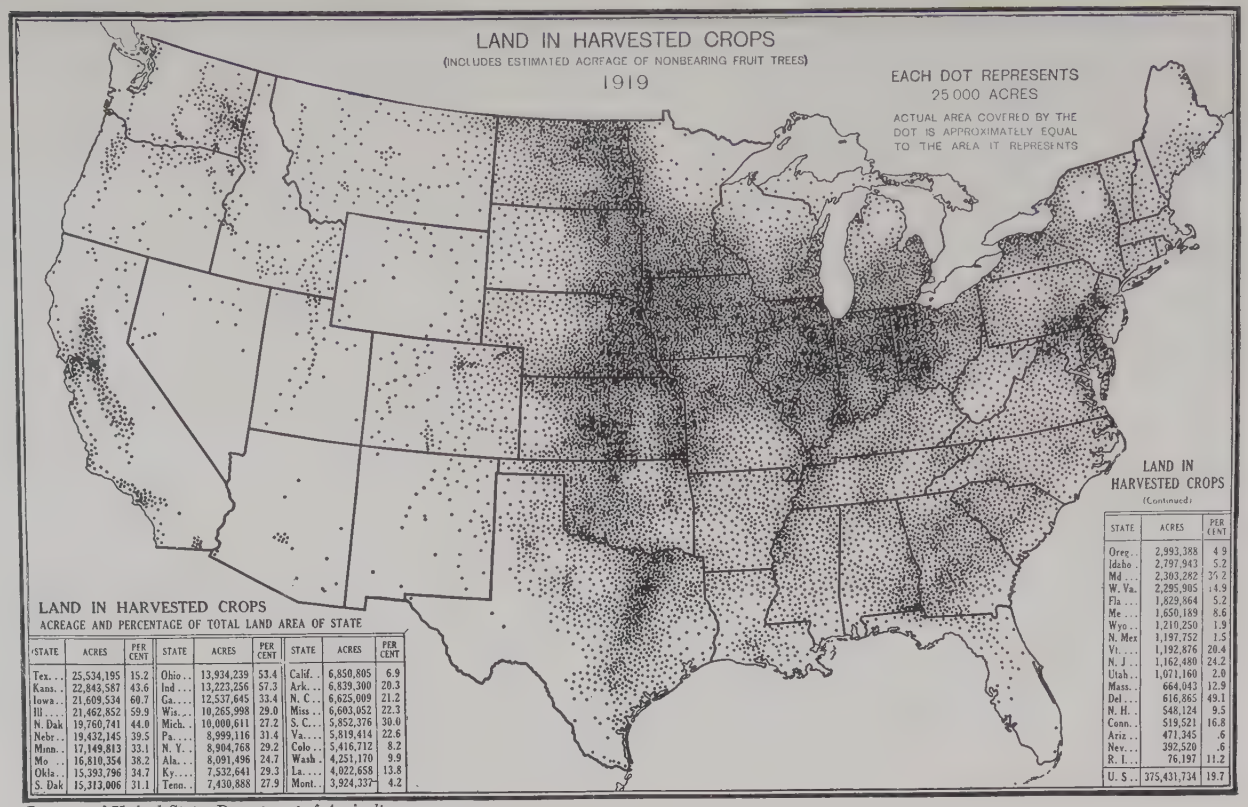
FIG. 138.—Average number of days per year with dense fog in the United States. (Reproduced from a drawing by Robert De C. Ward, in the *Geographical Review*, published by the American Geographical Society of New York.)

Courtesy of United States Geological Survey

FIG. 139.—The desert at the eastern base of the Sierra Nevada Mountains. The peak is Mount Whitney

Courtesy of United States Department of Agriculture—Atlas of American Agriculture

FIG. 140.—Average annual precipitation in Northwestern United States


LAND IN HARVESTED CROPS
(INCLUDES ESTIMATED ACREAGE OF NONBEARING FRUIT TREES)
1919
EACH DOT REPRESENTS
25 000 ACRES
ACTUAL AREA COVERED BY THE DOT IS APPROXIMATELY EQUAL TO THE AREA IT REPRESENTS

LAND IN HARVESTED CROPS

ACREAGE AND PERCENTAGE OF TOTAL LAND AREA OF STATE

STATE	ACRES	PER CENT	STATE	ACRES	PER CENT	STATE	ACRES	PER CENT
Tex. . .	25,534,195	15.2	Ohio . .	13,934,239	53.4	Calif. .	6,850,805	6.9
Kans. .	22,843,587	43.6	Ind . . .	13,223,256	57.3	Ark. . .	6,839,300	20.3
Iowa . .	21,609,534	60.7	Ga. . . .	12,537,645	33.4	N. C . .	6,625,009	21.2
Ill	21,462,852	59.9	Wis. . .	10,265,998	29.0	Miss . .	6,603,052	22.3
N. Dak	19,760,741	44.0	Mich. . .	10,000,611	27.2	S. C . .	5,852,376	30.0
Nebr. .	19,432,145	39.5	Pa. . . .	8,999,116	31.4	Va. . . .	5,819,414	22.6
Minn. .	17,149,813	33.1	N. Y. . .	8,904,768	29.2	Colo . .	5,416,712	8.2
Mo . .	16,810,354	38.2	Ala. . . .	8,091,496	24.7	Wash .	4,251,170	9.9
Okla. .	15,393,796	34.7	Ky. . . .	7,532,641	29.3	La. . . .	4,022,658	13.8
S. Dak	15,313,006	31.1	Tenn. .	7,430,888	27.9	Mont. .	3,924,337	4.2

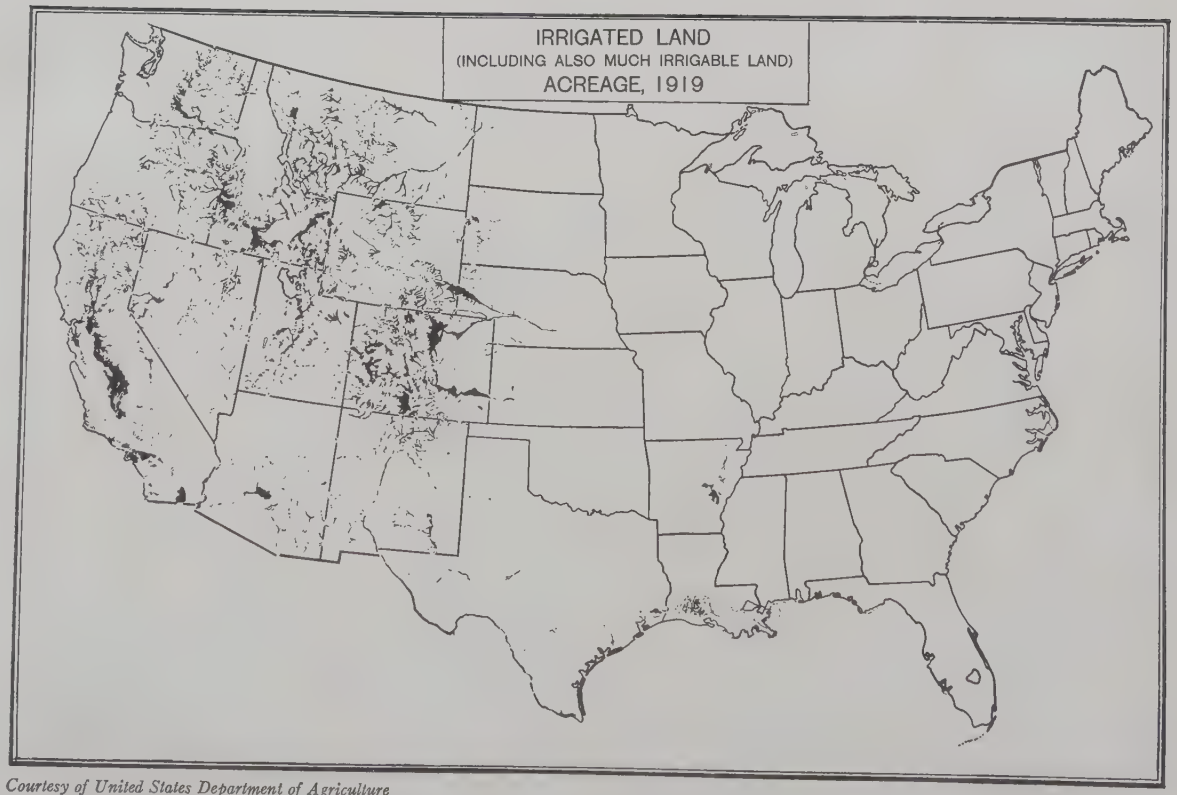
LAND IN HARVESTED CROPS

(Continued)

STATE	ACRES	PER CENT
Oreg. .	2,993,388	4.9
Idaho .	2,797,943	5.2
Md . . .	2,303,282	35.2
W. Va.	2,295,905	14.9
Fla . . .	1,829,864	5.2
Me . . .	1,650,189	8.6
Wyo . .	1,210,250	1.9
N. Mex	1,197,752	1.5
Vt. . . .	1,192,876	20.4
N. J . .	1,162,480	24.2
Utah . .	1,071,160	2.0
Mass. .	664,043	12.9
Del . . .	616,865	49.1
N. H . .	548,124	9.5
Conn. .	519,521	16.8
Ariz . .	471,345	.6
Nev. . .	392,520	.6
R. I. . .	76,197	11.2
U. S . .	375,431,734	19.7

Courtesy of United States Department of Agriculture

FIG. 141.—Land in harvested crops in the United States, 1919



Courtesy of United States Department of Agriculture

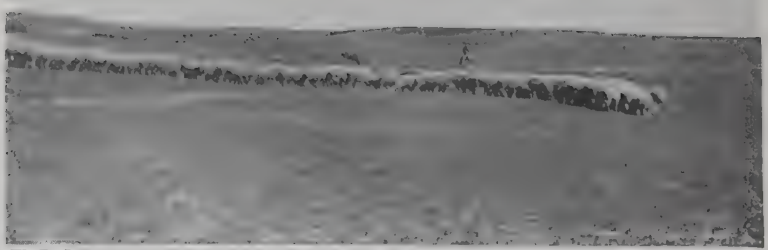
FIG. 142.—Irrigated land in the United States. Patches east of longitude 100° W. are rice fields

W. D. J.

FIG. 143.—Sheep grazing near a water hole in semi-arid Northern Patagonia, *ca.* 41° S., 70° W.

Courtesy of United States Department of Agriculture

FIG. 144.—Cattle grazing on the semi-arid plains of Western United States



W. D. J.

FIG. 145.—Flock of sheep on the semi-arid grasslands of Southeastern Mongolia.

Courtesy of American Museum of Natural History and Asia Magazine

FIG. 146.—An encampment of Khirghiz nomads, Western Asia

FIG. 147.—A part of the "Great Wall" of China. Note that it follows ridges

W. D. J.

FIG. 148.—A camel caravan northwest of Kalgan, China, bound for Mongolia

Courtesy of United States Department of Agriculture—F. Lamson-Scribner

FIG. 149.—Irrigated and unirrigated lands in Yakima Valley, Washington

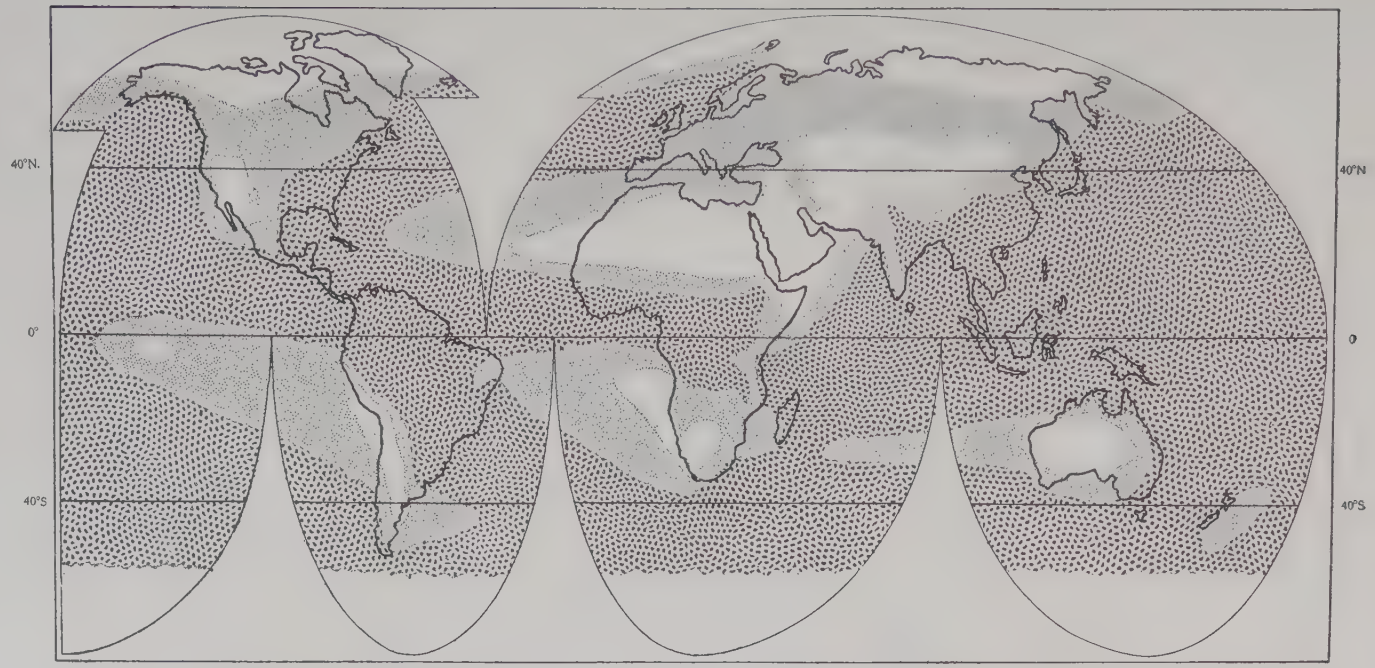


FIG. 150.—Distribution of rainfall over the continents and the oceans. Heavy dotted areas indicate abundant rain, fine dots indicate a medium amount, and white areas indicate scanty rainfall. (Adapted from W. Köppen, *Die Klimate der Erde.*)

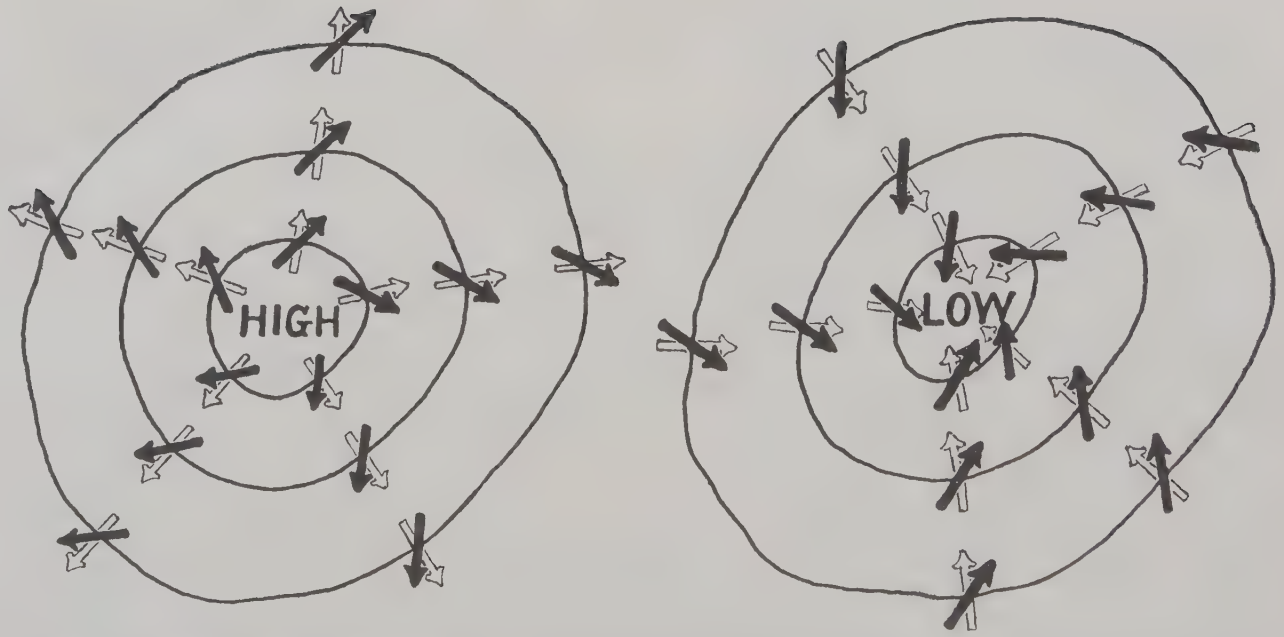


FIG. 151.—Diagram of wind directions in high- and low-pressure areas in the Northern Hemisphere. Note that the winds blow across the isobars diagonally, not perpendicularly; in all cases the actual wind is "deflected" to the right of the wind one might anticipate.

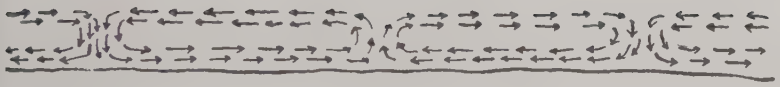


FIG. 152.—Vertical cross-section diagram to show circulation of air in high and low pressure areas. Note (*a*) that at the surface of the earth air moves, that is, winds blow, from high to low pressure areas; (*b*) that in the central portion of the HIGH there is descending air; and (*c*) in the central portion of the LOW ascending air. The vertical diameter of most moving high and low pressure areas is less than 5 miles, whereas the horizontal diameter is several hundred miles; therefore the vertical scale of this diagram is greatly exaggerated.

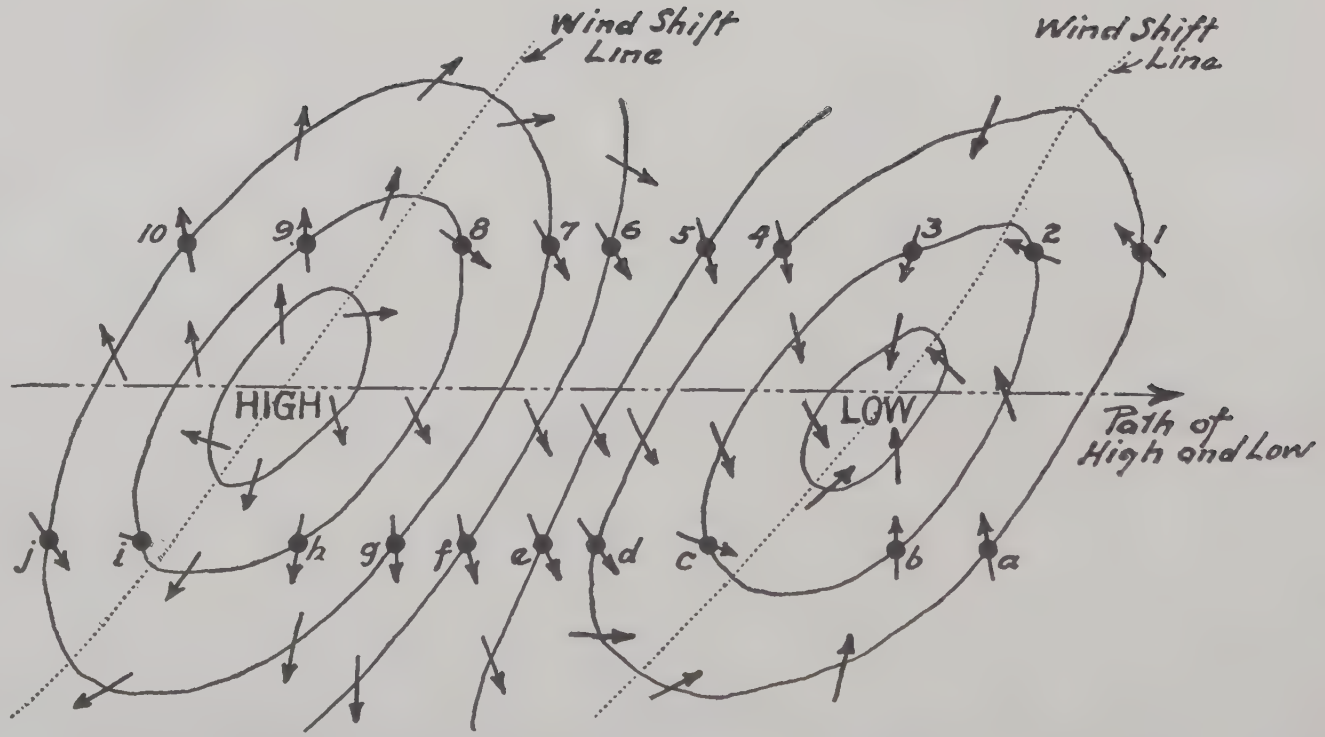
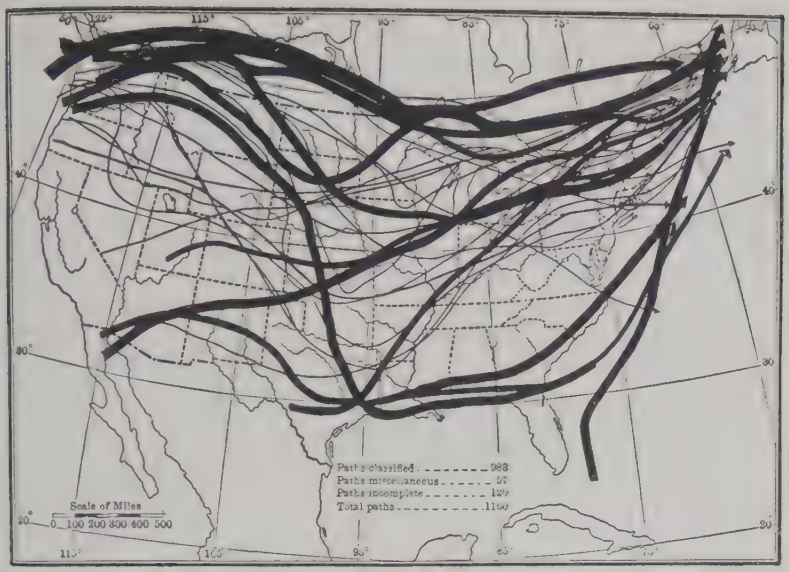
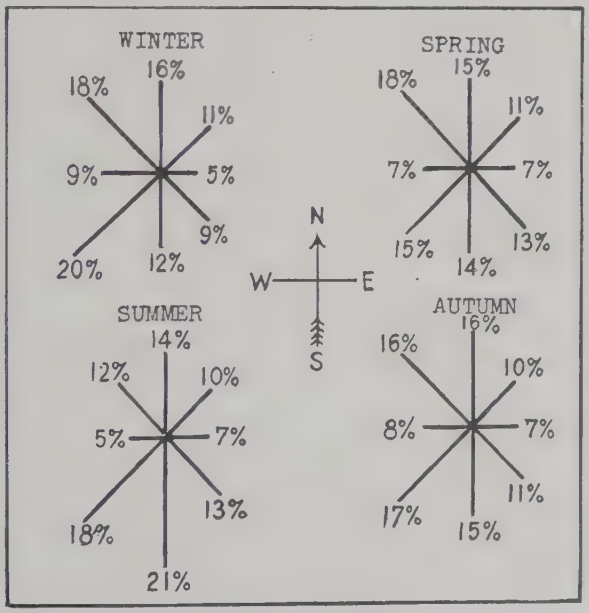


FIG. 153.—Diagrammatic weather map typical of Northern Hemisphere conditions. The isobars, indicated by the continuous lines, are not labeled, but pressures decrease toward the center of the LOW and out from the center of the HIGH. The small arrows fly with the winds, which blow into the LOW and out from the HIGH. Wind-shift lines, drawn as dotted lines, separate areas of southerly from areas of northerly winds. The numbered black dots indicate successive positions in the high and low pressure areas of two places, one south of the path



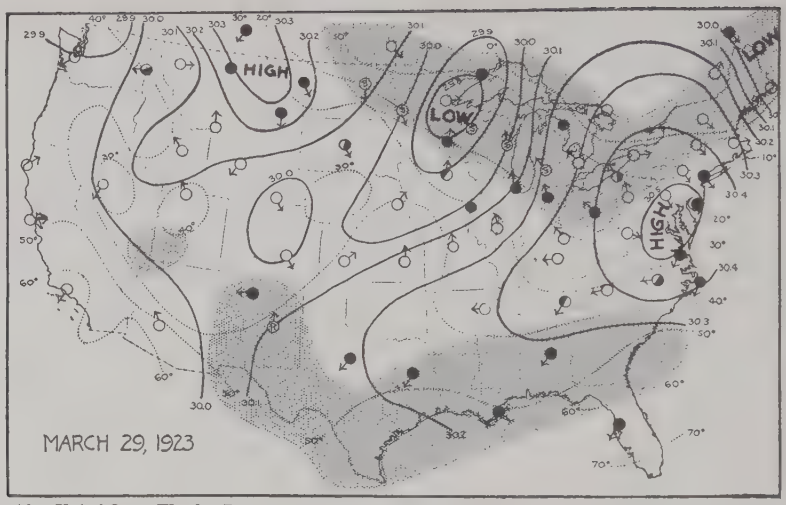
Courtesy of United States Weather Bureau—Van Cleef

FIG. 154.—Average paths of LOWS in the United States and Southern Canada



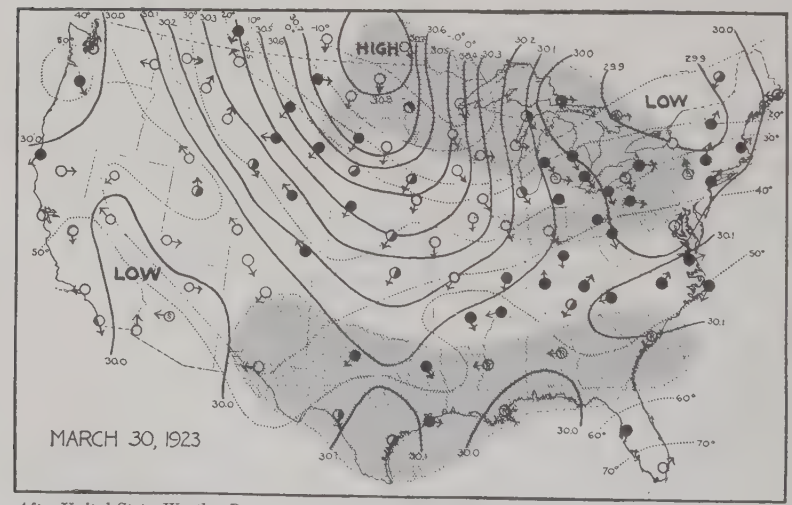
Courtesy of Maryland Weather Service

FIG. 155.—Wind directions at Baltimore, Maryland



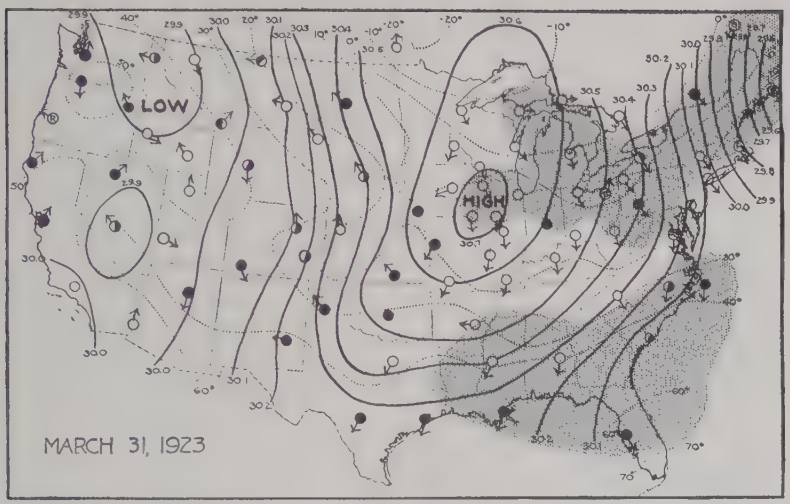
After United States Weather Bureau

FIG. 156



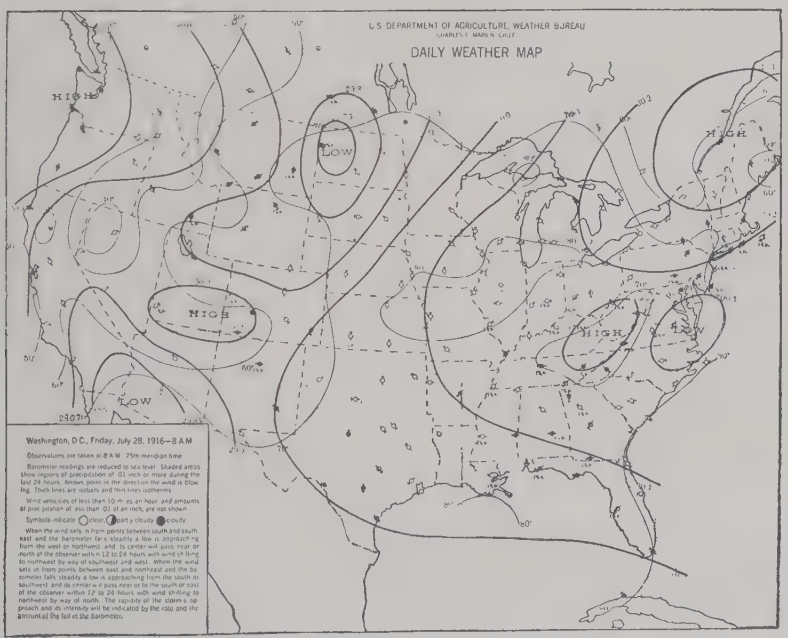
After United States Weather Bureau

FIG. 157



After United States Weather Bureau

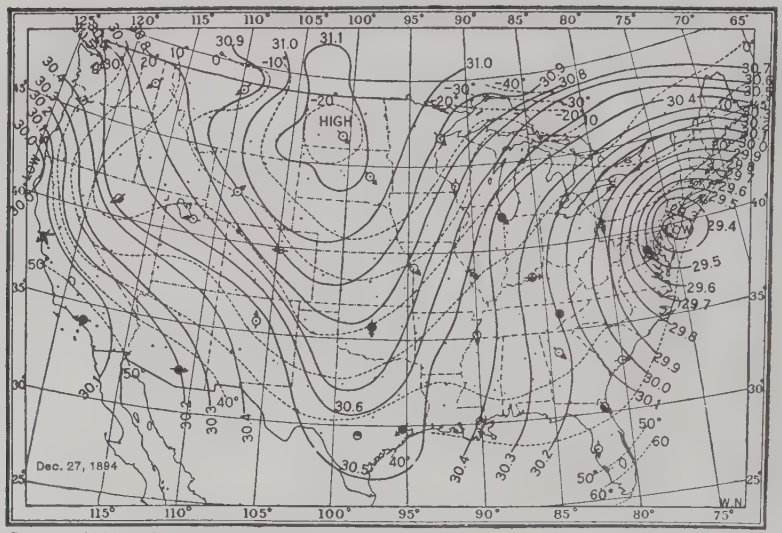
FIG. 158



After United States Weather Bureau

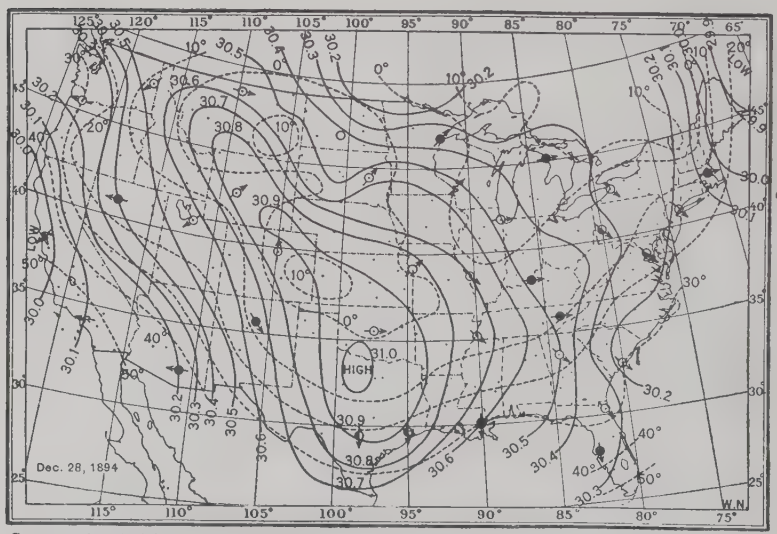
FIG. 159

DAILY WEATHER MAPS OF THE UNITED STATES



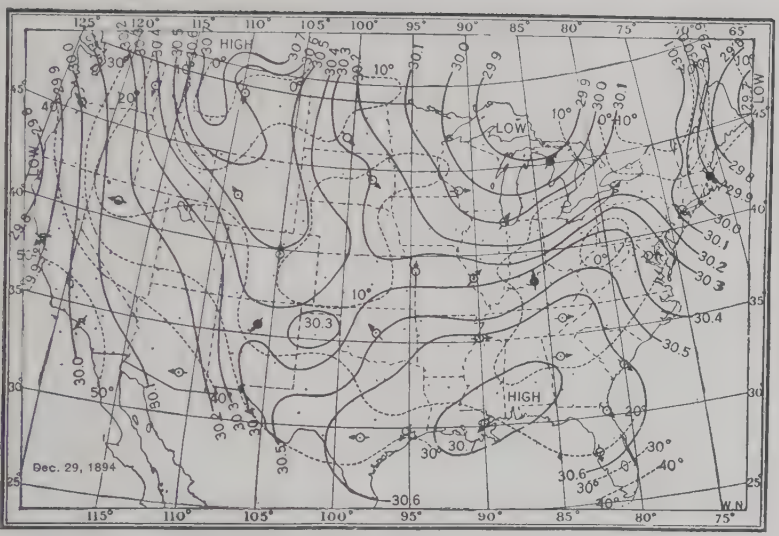
Courtesy of United States Weather Bureau

FIG. 160



Courtesy of United States Weather Bureau

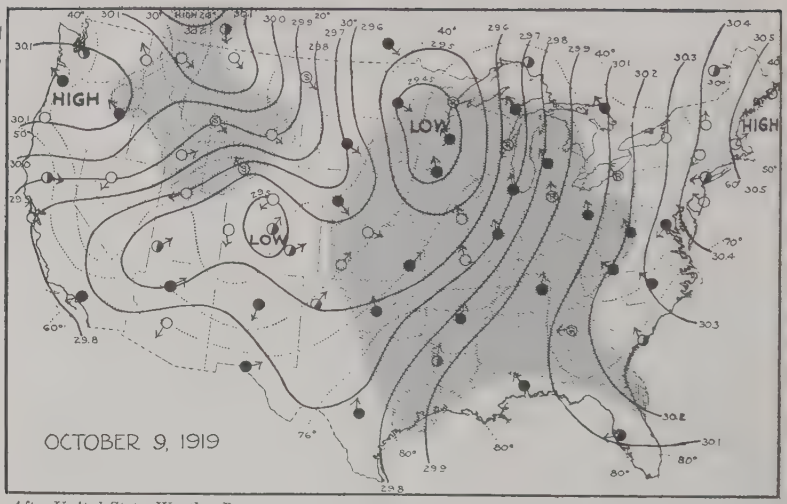
FIG. 161



Courtesy of United States Weather Bureau

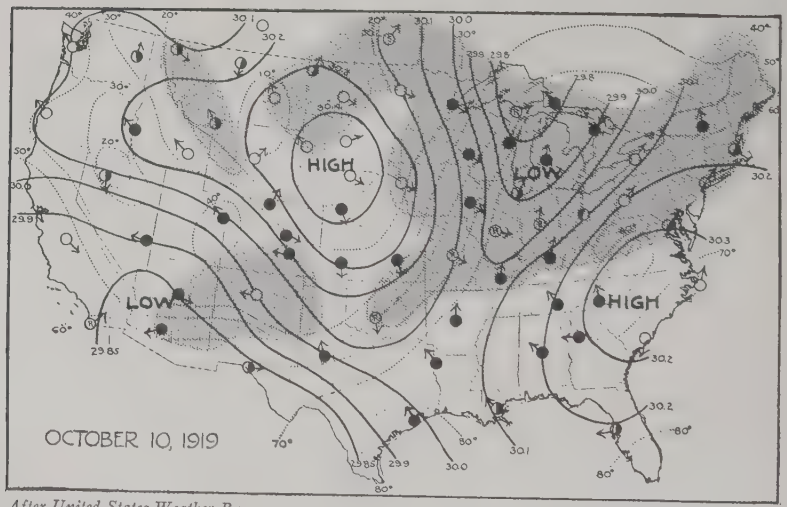
FIG. 162

DAILY WEATHER MAP OF THE UNITED STATES



After United States Weather Bureau

FIG. 163



After United States Weather Bureau

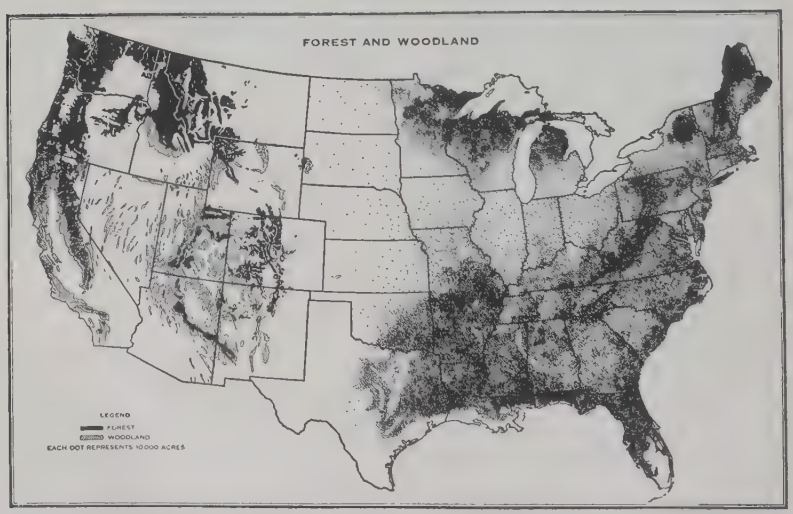
FIG. 164

Courtesy of Canadian Pacific Railway

FIG. 165.—A tourist hotel amid grand mountain scenery. Banff, Alberta, Canada.

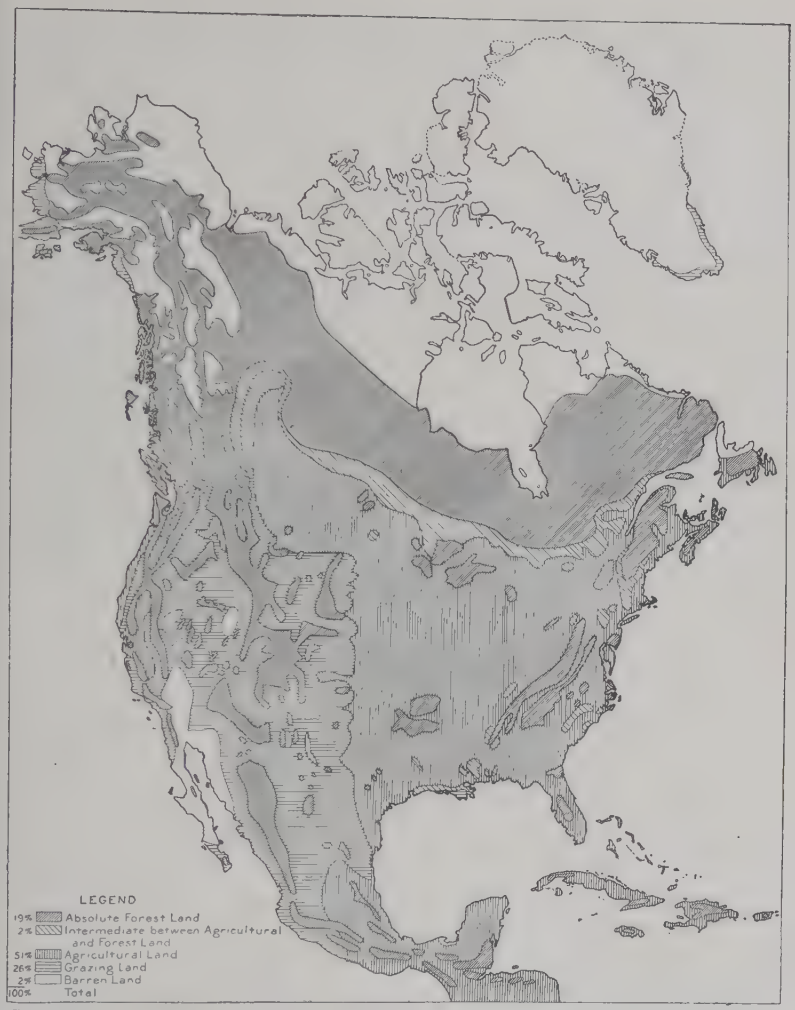
Courtesy of Official Information Bureau of Switzerland—Albert Steiner

FIG. 166.—Winter aspect of St. Moritz, an all-year resort in the Swiss Alps. Elevation *ca.* 6,000 feet.



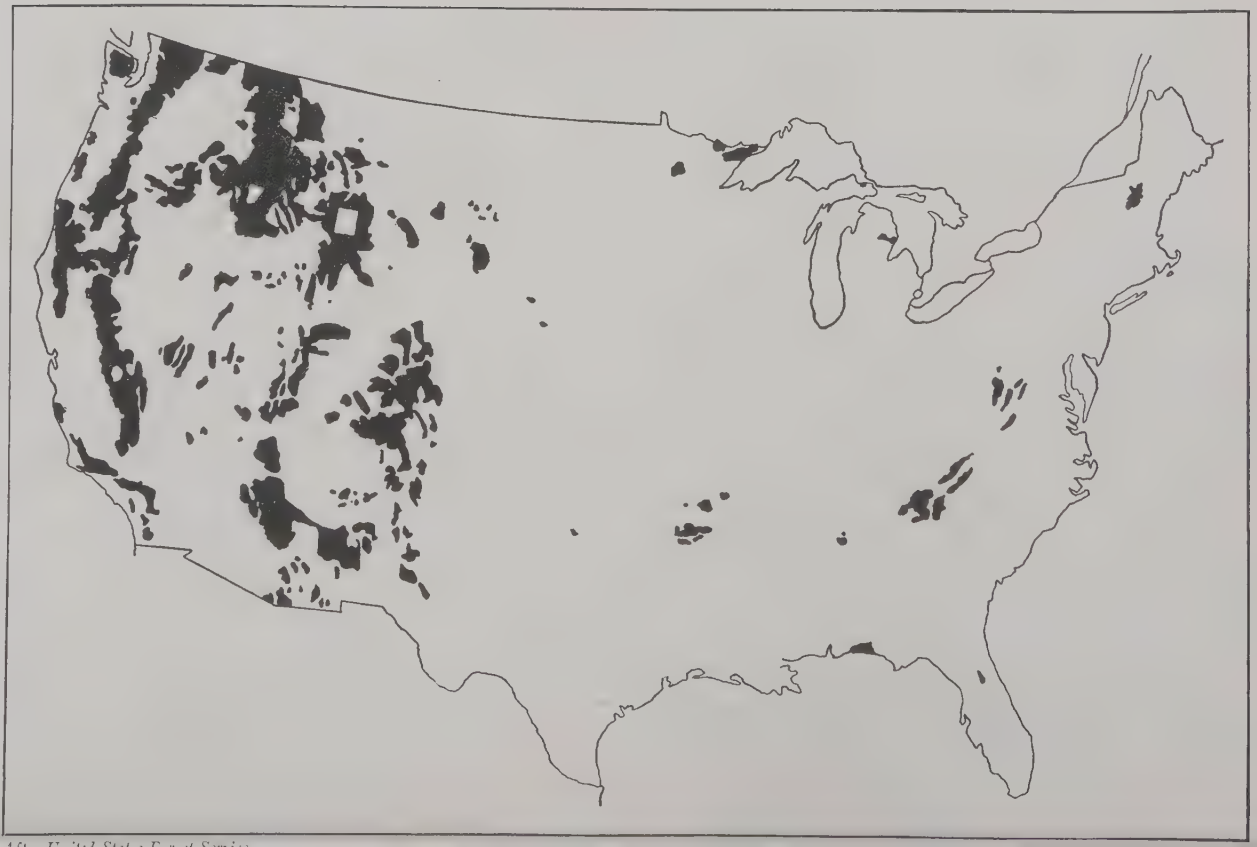
Courtesy of United States Department of Agriculture

FIG. 167.—Distribution of forest and woodland in the United States. This map is of value in showing relative amounts of forest and woodland in different parts of the country, but *not* in showing proportion of area in forest and woodland in a given region.



Courtesy of United States Forest Service—Raphael Zon

FIG. 168.—Potential use of the land in North America



Fred. Boissonnas

FIG. 170.—Cattle and stone huts on a high summer pasture in Switzerland

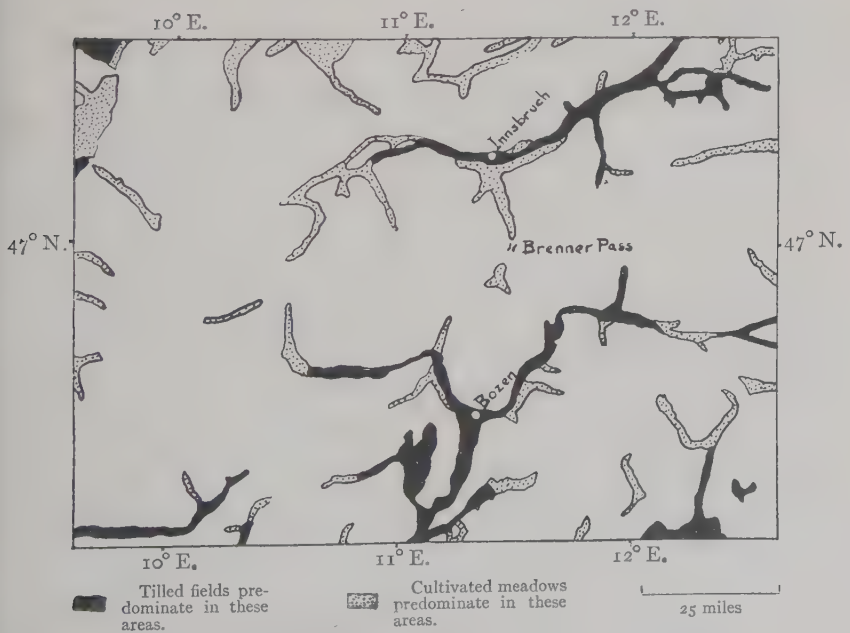


FIG. 171.—Cultivated areas in the Central Tyrolean Alps (after Krebs)

W. D. J.

FIG. 172.—Hay land in Estes Park, Colorado, at an altitude of about 7,500 feet

W. D. J

FIG. 173.—Snow fences erected to protect a railroad track in mountains. Boreas Pass, Colorado, elevation 11,480 feet.

Courtesy of American Geographical Society—Flaherty

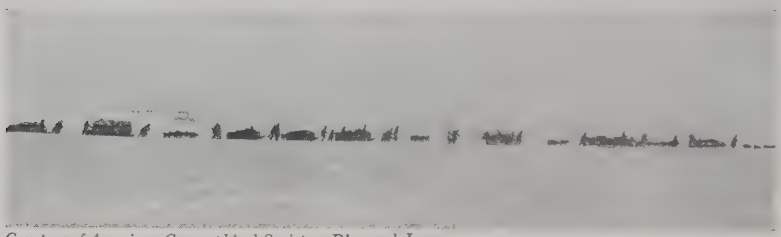
FIG. 174.—The northern edge of the Canadian Forest south of Hudson Strait. (From the *Geographical Review*, published by the American Geographical Society of New York.)

After H. P. Steensby

FIG. 175.—The zone inhabited by Eskimos on the advent of white men. (After a map in the *Geographical Review*, published by the American Geographical Society of New York.)

Courtesy of American Geographical Society—Czaplicka

Fig. 176.—Reindeer grazing on the tundra of the Lower Yenisei River Basin, Siberia. The low-hanging clouds are characteristic. Summer.



Courtesy of American Geographical Society—Diamond Jenness

Fig. 177.—Dog train of sledges on the Arctic border of Canada, *ca.* 115° W. Long. Winter. (From the *Geographical Review*, published by the American Geographical Society of New York.)

Courtesy of Canadian Geological Survey—Diamond Jenness

Fig. 178.—Skin tents of Eskimos on the Arctic Coast of Canada, *ca.* 115° W. Longitude. Summer. (From the *Geographical Review*, published by the American Geographical Society of New York.)

Courtesy of American Geographical Society—Flaherty

FIG. 179.—Eskimo fishing from a native canoe made of skins stretched over a framework of bone and driftwood. (From the *Geographical Review*, published by the American Geographical Society of New York.)

Courtesy of American Geographical Society—Isachsen

FIG. 180.—Skiing and sledging in Spitzbergen. Winter. (From the *Geographical Review*, published by the American Geographical Society of New York.)

W. D. J.

FIG. 181.—A terraced mountain slope in the outer Himalayas, near Darjeeling, India

Courtesy of American Geographical Society—Isaiah Bowman

FIG. 182.—Cultivated valley floor in the Andes of Southern Peru in latitude 13° 15′ S. (From *The Andes of Southern Peru*, published by the American Geographical Society of New York.)

W. D. J

FIG. 183.—Terraced lower slopes of a cone of alluvial material in the valley of the Jhelum, outer Himalayas, Northwestern India.

W. D. J

FIG. 184.—The highly cultivated intermontane basin of Kashmir. The fields in the foreground are enclosed by ridges to permit flooding for rice. The contrast between cultivated basin and uncultivated mountain slopes is sharp.

W. D. J.

Fig. 185.—The Bernina Alps south of St. Moritz, Switzerland, showing serrate peaks, snow fields, a glacier, and the head of a glacial stream.

Courtesy of American Geographical Society—Blanchard

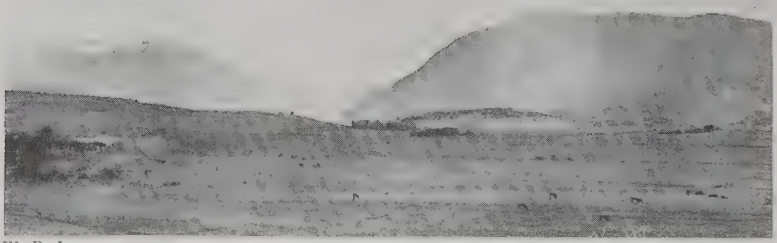
Fig. 186.—The valley of the Bonne, in the French Alps, south of Grenoble; a U-shaped, ice-scoured valley with walls of bare rock. (From the *Geographical Review*, published by the American Geographical Society of New York.)

Kiser

FIG. 187.—Cirque, partly occupied by Grinnell Glacier and Grinnell Lake, Glacier National Park, Montana.

W. D. J.

Fig. 188.—A western fjord of Lago Nahuel Huapi, Southern Andes. The view is eastward; in the distance is the lower country at the border of the mountains, shown in the foreground of Figure 189.



W. D. J

Fig. 189.—Lago Nahuel Huapi, Southern Andes, seen from the east. In the foreground is a plain of glacial outwash, back of which is the morainal dam at the eastern end of the lake. In the far distance the western fiorded arms of the lake reach into the heart of the Andes.

W. D. J.

FIG. 190.—Typical features produced by mountain glaciation. Eastern end of Lago Nahuel Huapi, Southern Andes, latitude 41° S. Note the relation of this map to the features shown in Figure 189.

W. D. J.

FIG. 191.—The distribution and extent of former glaciers in the Southern Andes of Argentina between latitude 39° 40′ S. and 41° 15′ S. Present-day lakes are shown in black; former glaciers in stipple. The Chilean side of the boundary is not mapped, but it also is characterized by many lakes and extensive glaciated areas. The large, much branched lake in the southern part of the area is Nahuel Huapi, shown in Figures 188–190.

Courtesy of Willard R. Jillson

FIG. 192.—The partially eroded volcanic cone of Mount St. Helens, Washington, rising above the forested Cascade Range.

W. D. J.

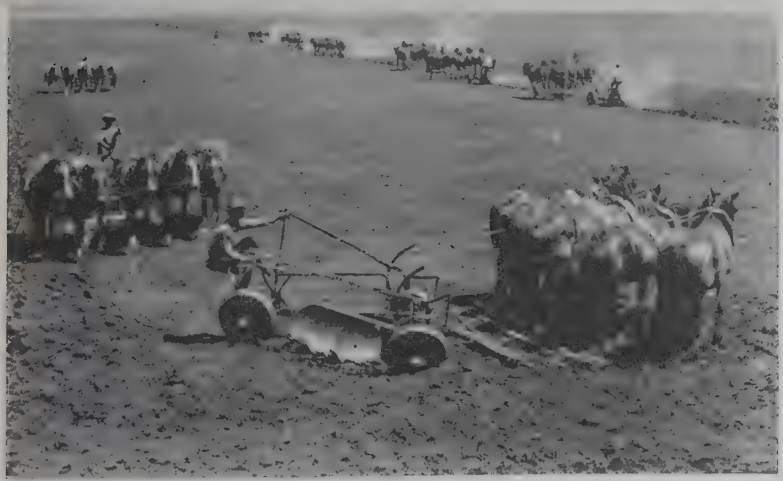
FIG. 193.—The volcanic cone of Osorno, Southern Chile, about 41° S.

Courtesy of United States Geological Survey

FIG. 194.—Transportation routes in a narrow mountain valley. Ogden Canyon, Wasatch Mountains, Utah.

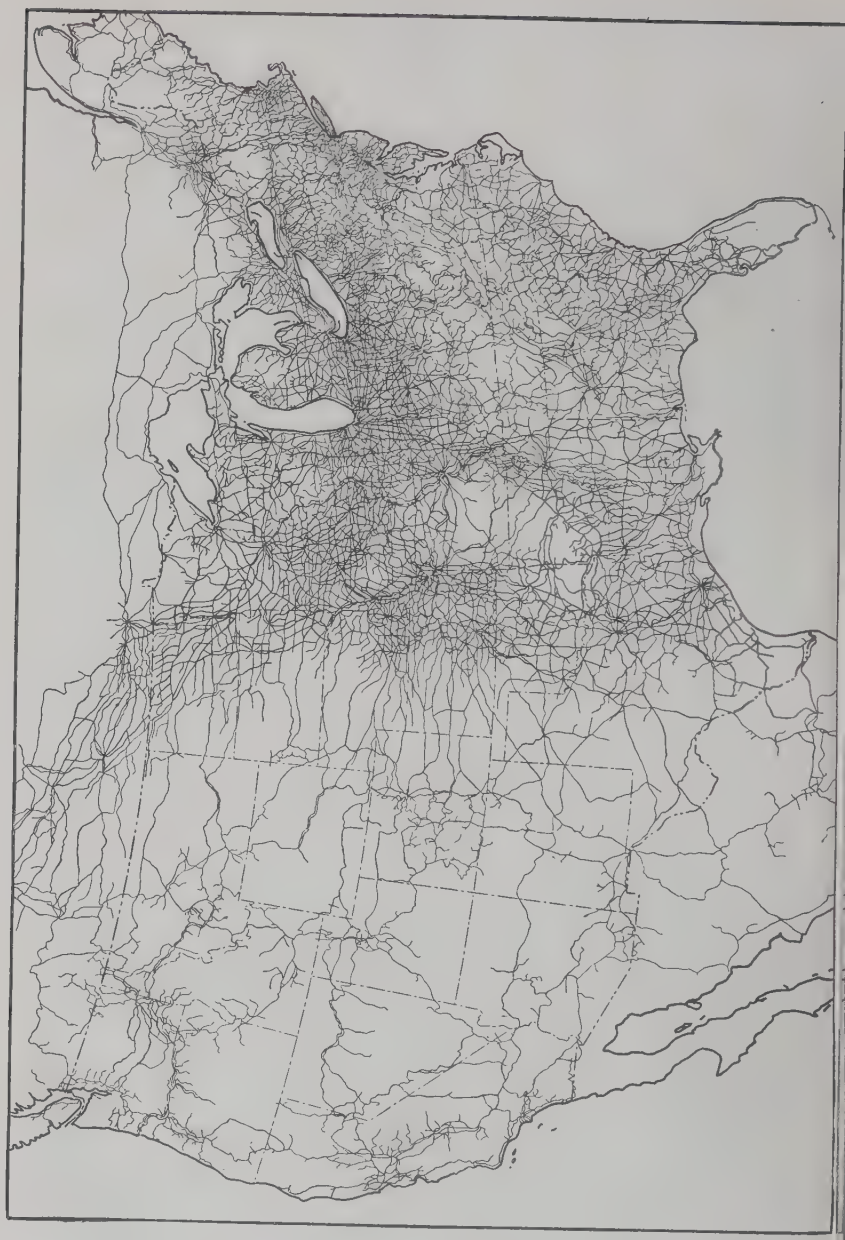
Detroit Photographic Company

FIG. 195*a*.—Railroad climbing to Marshall Pass, Colorado. Mount Ouray to right of pass



Courtesy of Australian Government

FIG. 195*b*.—Plowing wheat land on the plains of New South Wales, Australia



Chr. Franz

FIG. 197.—A valley in the Schwarzwald, Southwestern Germany, showing forested upper slopes, cultivated lower slopes, and typical hill country road and railroad.

W. D. J.

FIG. 198.—A scene in the Schwarzwald, Southwestern Germany, showing a typical farmstead. The poles and billets have been obtained from the cut-over land in the foreground.

W. D. J.

FIG. 199.—Use of the land in the hill country of Eastern Kentucky; corn occupies the whole of the precious floodplain, leaving only the dry, rocky stream bed for a road. Most hill slopes are forested.

W. D. J.

FIG. 200.—Hill country of Eastern Kentucky, covered with deciduous forest

W. D. J.

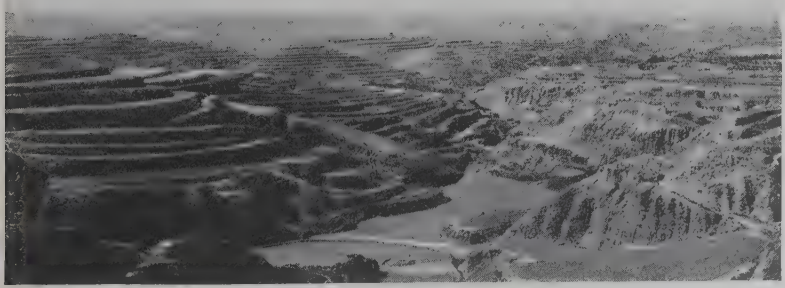
FIG. 201.—A farmstead in the hill country of Eastern Kentucky.

W. D. J.

Fig. 202.—Corn in a forest of girdled trees on a steep slope in the hill country of Eastern Kentucky.

W. D. J.

FIG. 203.—The hill country of western Chili Province, China. Note the small amount of land available for cultivation.



W. D. J.

FIG. 204.—Hill country where terracing is facilitated by a deep mantle of loess. Near Taiyuan-fu, Shansi Province, China.

Courtesy of United States Department of Agriculture

FIG. 205.—A farmstead in the "Valley of East Tennessee." Cattle-raising is an important industry.

Courtesy of United States Army Air Service

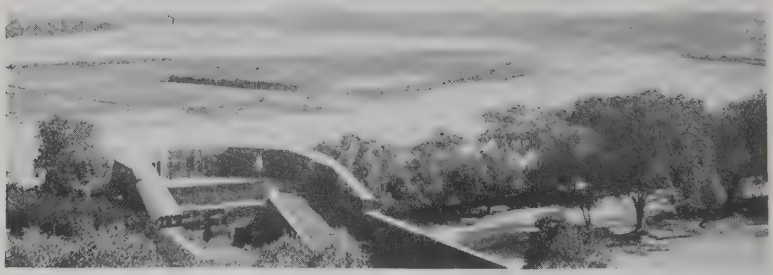
FIG. 206.—The canyon of the Yellowstone River

Courtesy of United States Geological Survey

FIG. 207.—The Grand Canyon of the Colorado River

W. D. J.

Fig. 208.—The Illinois River and a tilled section of its floodplain, as seen from Starved Rock, Illinois.



W. D. J.

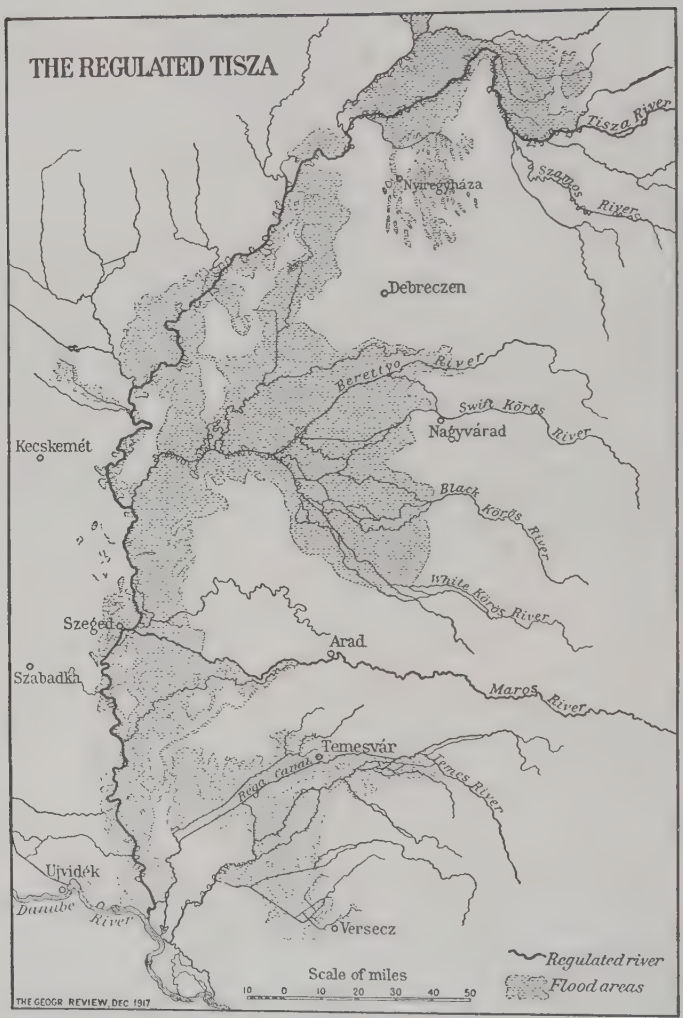
Fig. 209.—A stretch of the Ganges River and its floodplain, near Agra, India. The building in the distance is the Taj Mahal, a wonderfully beautiful structure built by Mohammedan conquerors from tribute levied on the farming population of the productive Upper Ganges Plain.

W. D. J.

FIG. 210.—The Mississippi River and its floodplain, showing backwaters, forests, and a railroad line. A few miles below the mouth of the Wisconsin River.

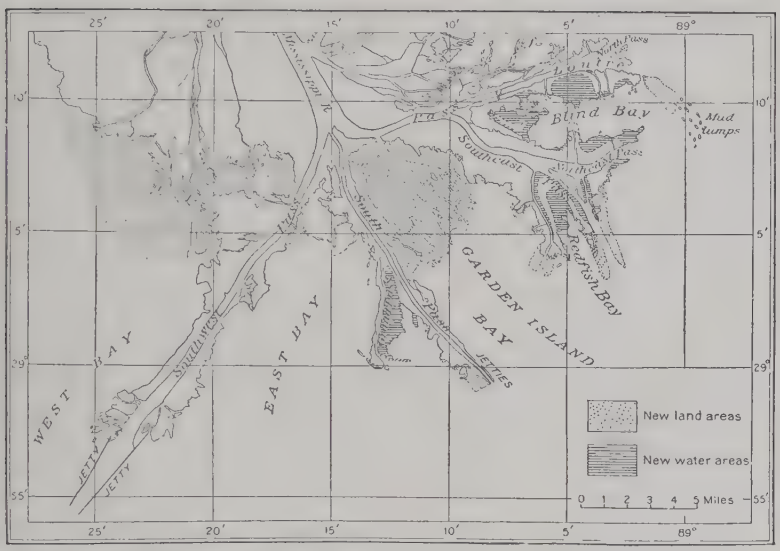
W. D. J.

FIG. 211.—The Wisconsin River and its floodplain near Mazomanie, Wisconsin. Fresh, sandy alluvium is bare; older alluvium is forested or is cleared for farms.



Courtesy of American Geographical Society—B. C. Wallis

FIG. 212.—The lower course of the Tisza River, Hungary–Yugo-Slavia. The river has been regulated by eliminating meanders and the "flood areas" are gradually being reclaimed. (From the *Geographical Review*, published by the American Geographical Society of New York.)



Courtesy of United States Geological Survey

FIG. 213.—The outer margin of the Mississippi Delta, showing recent changes

W. D. J.

Fig. 214.—Native barge of hay on the Hugli River, a distributary of the Ganges. Near Calcutta.

Courtesy of United States Coast and Geodetic Survey

FIG. 215.—A section of the Mississippi Delta a few miles above New Orleans, showing land holdings (boundaries in solid lines), drainage ditches (dotted lines), and the wooded swamps which border the cultivated zone of natural levees. (Only the margins of the swamps are mapped, but they extend beyond the limits of the map.) Most of the houses are close to the river.

Courtesy of United States Weather Bureau

FIG. 216.—The Mississippi River in flood, a stretch of levee, and a bayou, a short distance above New Orleans.

Courtesy of United States Weather Bureau

FIG. 217.—A knoll of refuge during a flood of the Mississippi River. Arkansas.

Courtesy of United States Weather Bureau

FIG. 218.—Flood refugees on levee of Lower Mississippi River

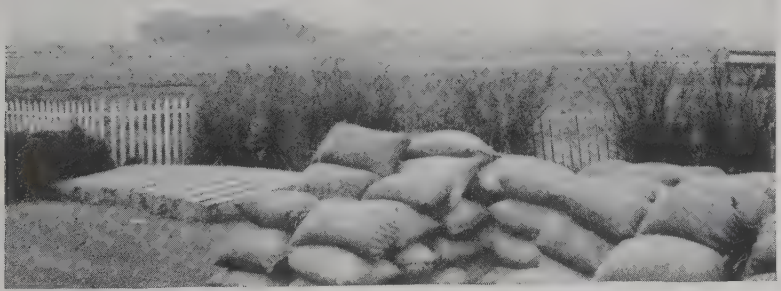
Courtesy of United States Weather Bureau

FIG. 219.—The levee at New Orleans, with a flooded wharf and a street below the level of the river.

FIG. 220.—The larger delta plains of the earth. The dots show general location, but not relative size or shape

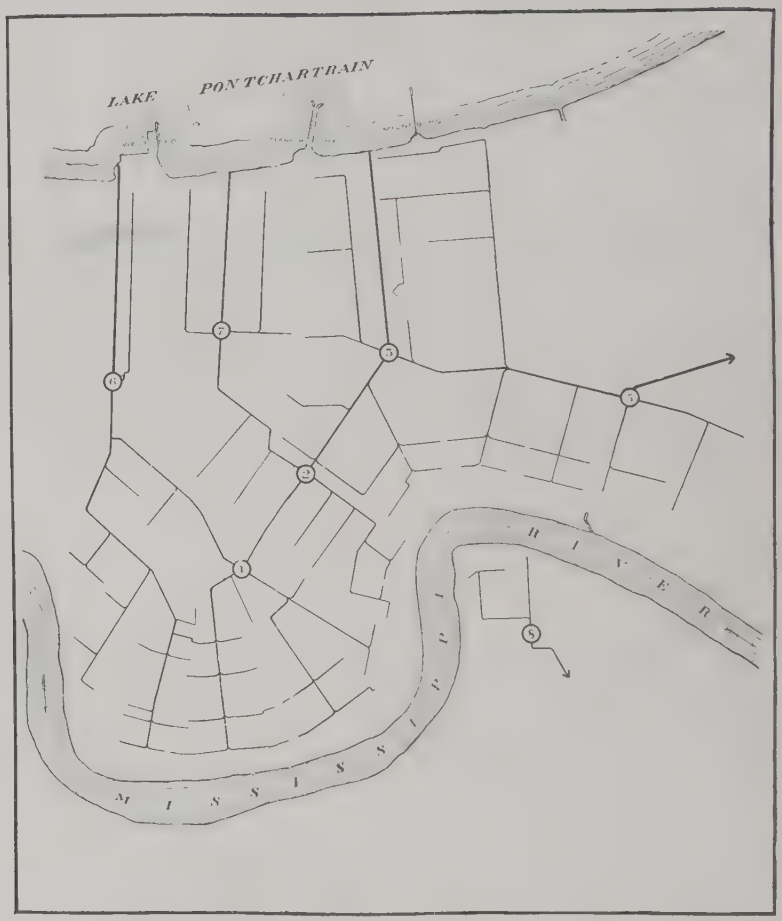
W. D. J.

FIG. 221.—The Lower Ganges River as it flows through its low, flat, delta plain



W. D. J.

FIG. 222.—Rice fields on the Ganges Delta. Bags of rice awaiting shipment. The clump of trees in the middle distance marks the site of a village on slightly higher ground.



After New Orleans Sewage and Water Board

Fig. 223.—The New Orleans drainage system, 1922. Water is drained *away* from the river to Lake Pontchartrain and two bayous. Compare this map with the topographic maps of New Orleans and vicinity. Canals are shown by black lines, pumping stations by circles.

W. D. J.

FIG. 224.—Pontoon bridge across river at Calcutta, India

Courtesy of American Geographical Society

FIG. 225.—The Pampas of Argentina, with the Paraná River in the distance. (From the *Geographical Review*, published by the American Geographical Society of New York.)

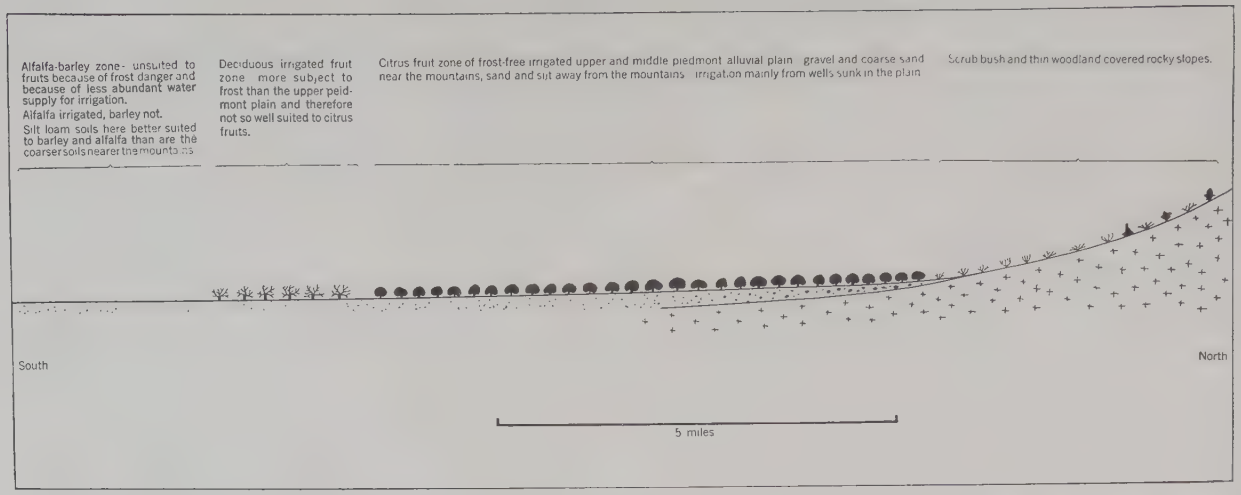
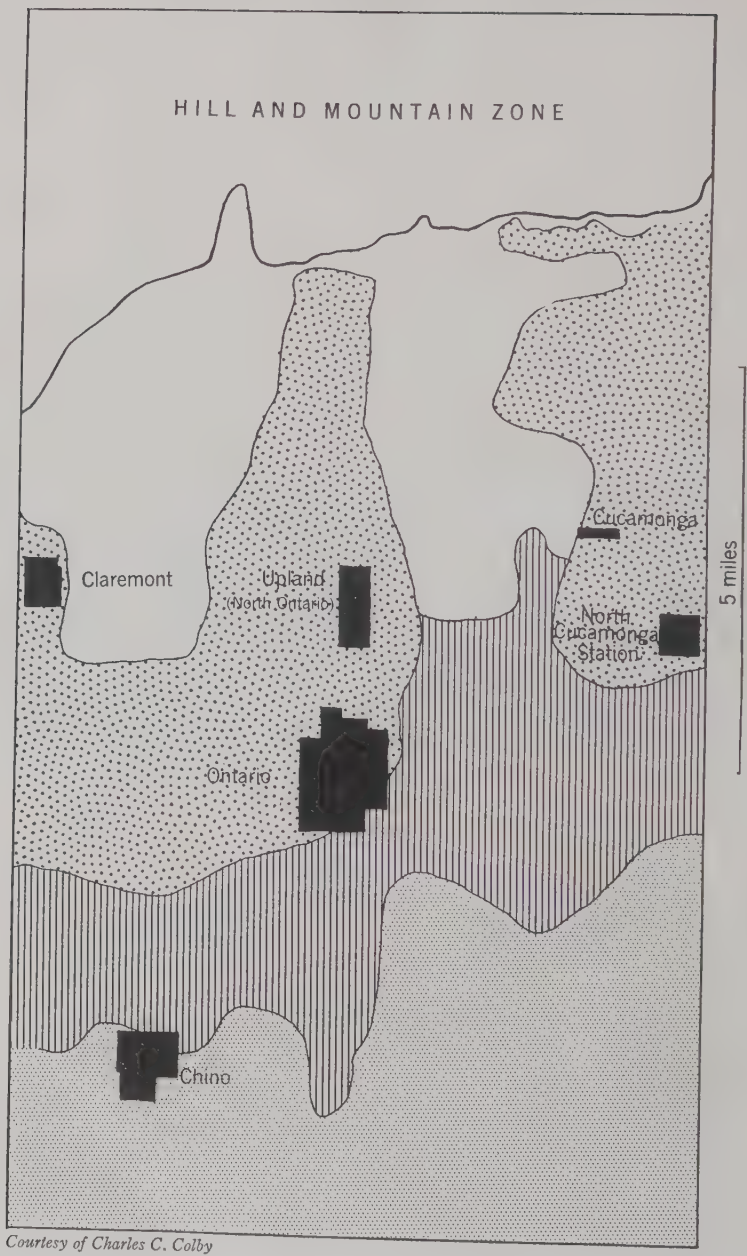

Alfalfa-barley zone- unsuited to fruits because of frost danger and because of less abundant water supply for irrigation.
Alfalfa irrigated, barley not.
Silt loam soils here better suited to barley and alfalfa than are the coarser soils nearer the mountains.
Deciduous irrigated fruit zone more subject to frost than the upper piedmont plain and therefore not so well suited to citrus fruits.
Citrus fruit zone of frost-free irrigated upper and middle piedmont alluvial plain gravel and coarse sand near the mountains, sand and silt away from the mountains irrigation mainly from wells sunk in the plain
Scrub bush and thin woodland covered rocky slopes.
South
North
5 miles

FIG. 226.—Geographic cross-section through Ontario, California, including a part of the San Bernardino Mountains and the piedmont plain at their base. (Data furnished by Charles C. Colby.)



Courtesy of Charles C. Colby

FIG. 227.—Land utilization on the piedmont plain in the Cucamonga, California, District. Legend on opposite page.

The following types of land utilization are shown on the map, Figure 227.

Citrus fruits, oranges and lemons. Within these areas there are tiny spots and strips of waste land, mostly along the distributary drainage courses.

Deciduous fruits, chiefly peaches, walnuts, apricots, and grapes. There is some mixture of citrus and deciduous fruits along the line between the two types of areas.

General farming, mostly alfalfa and dairying in the north, grading into barley and sheep in the south. Many of the dairy farms have small groves of deciduous fruit trees about the farm houses.

Waste or idle land.

Towns.

This map should be compared with the Cucamonga topographic map [posted], and the relations between land utilization and land forms, soils, and water conditions worked out as suggested in the questions on p. 60.

Courtesy of Charles C. Colby

FIG. 228.—The lower piedmont plain south of Ontario, California, looking up toward the San Bernardino Mountains. Alfalfa in the foreground, deciduous fruits in the middle distance.

Courtesy of Charles C. Colby

FIG. 229.—"Raw land" on the piedmont plain near Upland, California, showing the natural vegetation on land similar to that used for orange groves. Cucamonga Peak in the left background.

Courtesy of Charles C. Colby

FIG. 230.—The piedmont plain at the base of the Wasatch Mountains, Utah. The crop in the foreground is alfalfa; in the middle distance are deciduous fruit trees and Lombardy poplars—all irrigated.

Courtesy of United States Geological Survey

FIG. 231.— The Upper Piedmont Plain near San Bernardino, California. Orange groves in the foreground, the San Bernardino Mountains in the background.

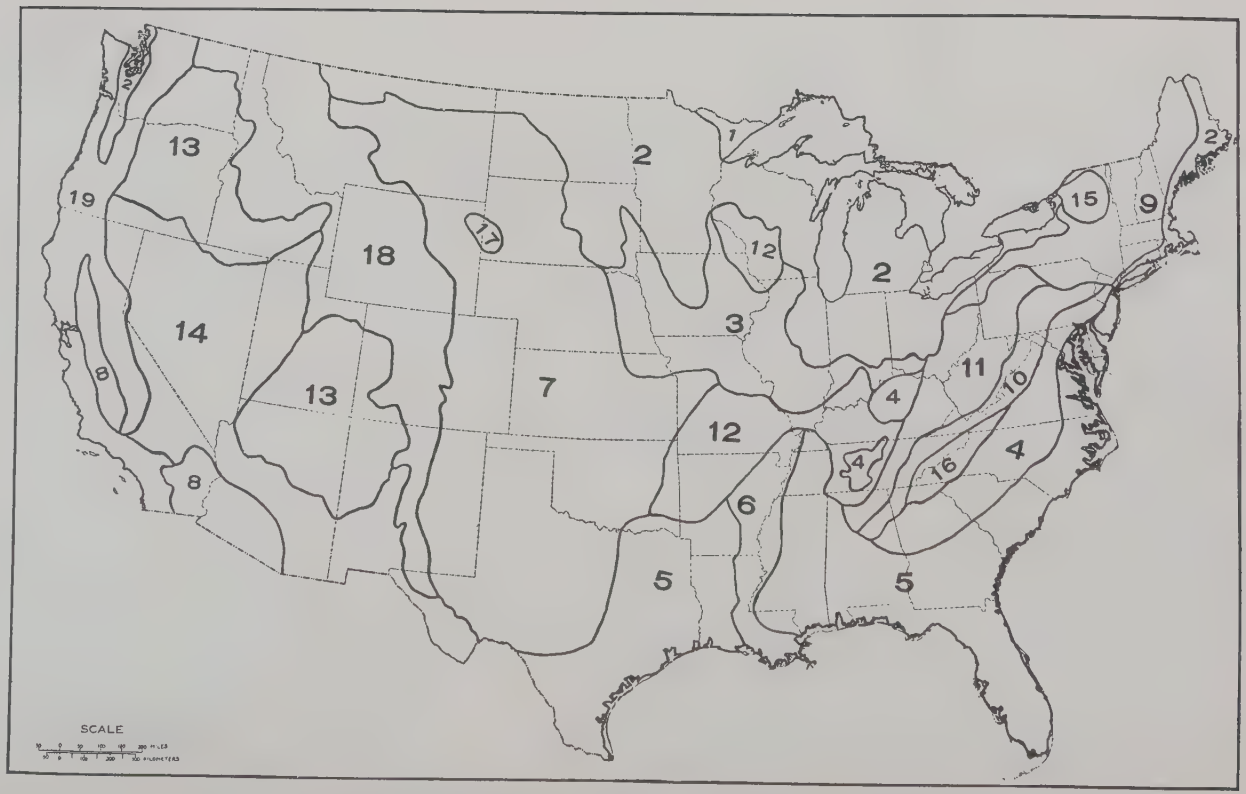


FIG. 232.—Land-form divisions of the United States. Boundaries are taken, with slight modifications, from the map of physiographic regions of the United States, by N. M. Fenneman and others. Legend on opposite page.

LEGEND TO ACCOMPANY THE MAP OF LAND-FORM DIVISIONS OF THE UNITED STATES, FIG. 232

This map portrays only land-form divisions of the country which are sufficiently extensive to be shown on a map of small scale. Most of the boundaries follow lines drawn on the map, "Physiographic Divisions of the United States," by N. M. Fenneman and others. The areas selected, the criteria by which they are differentiated, and the names by which they are designated, however, are quite different in most cases from those adopted for the Fenneman map.

PLAINS

1. Ice-scoured plain. Characterized by rock-basin lakes, marshes, much bare rock, patches of thin till, unsystematic drainage.
2. Younger moraine plains. Characterized by moraine lakes, marshes, lacustrine plains, glacial outwash, a thick mantle of till widely varied in composition and loess mantled in places, unsystematic drainage. (In Northern Michigan and New England there are some small ice-scoured districts.)
3. Older moraine plain. Characterized by weathered till soils, well-drained surfaces, systematic stream development, glacial features subordinate.
4. Plains of residual soil. Characterized by weathered soils intimately related to and varying with the bedrock, numerous hills.
5. Coastal plains. Characterized by extensive flat surfaces, coastal marshes and dunes, sandy soil, many floodplains and delta plains.
6. Flooded alluvial plain. Characterized by flat surface, with much marsh area, numerous streams, natural levees.
7. Plains of old alluvium and residual soil. Characterized by stream terraces, piedmont alluvial plains, hilly districts, sections where the soil is intimately related to bedrock, excellent drainage.
8. Piedmont alluvial plains. Characterized by deep deposits of detritus from adjacent ranges, gentle slopes, coarse-grained soils.

HILL COUNTRY

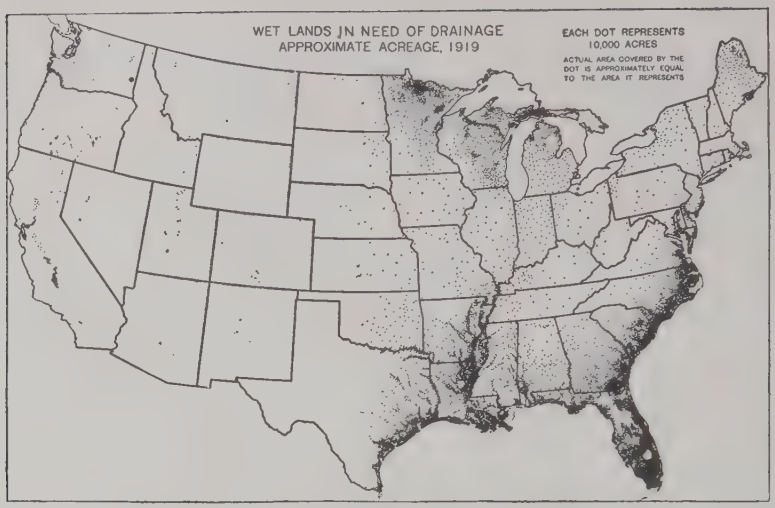
9. Glaciated hill country. Characterized by morainal and ice-sourced features. (The White Mountains within this region cannot be shown separately on a map of this scale, although they properly are mountains.)
10. Ridge-and-valley hill country. Characterized by parallel and alternating ridges and valleys, with longitudinal and transverse streams.
11. Much-dissected, unglaciated hill country. Characterized by narrow, steep-sided valleys, no extensive upland flats, systematic drainage.
12. Hill country with much undissected upland. Characterized by pronounced upland flats between tracts of hill and valley.

PLATEAUS

13. Tableland plateaus. Characterized by extensive upland flats, few but deep canyons.
14. Basin-and-range plateau. Characterized by waste-filled intermontane valleys and basins, piedmont plains, coarse soils, interior drainage, salt lakes.

MOUNTAINS

15. Adirondack Mountains. Characterized by strongly glaciated surfaces, low altitude, some plateaulike areas.
16. Great Smoky Mountains. Characterized by broken ranges, deep, steep-sided valleys.
17. Black Hills. Characterized by low altitude, canyons.
18. Rocky Mountains. Characterized by complex ranges, peaks, and plateaus, numerous intermontane basins, glaciation at high levels particularly in the north.
19. Pacific Mountains. Characterized by ranges and peaks without extensive plateaus, glaciation at high levels particularly in the north.

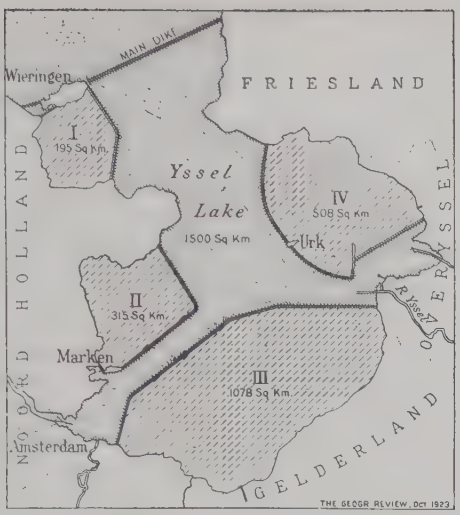

WET LANDS IN NEED OF DRAINAGE
APPROXIMATE ACREAGE, 1919
EACH DOT REPRESENTS
10,000 ACRES
ACTUAL AREA COVERED BY THE
DOT IS APPROXIMATELY EQUAL
TO THE AREA IT REPRESENTS

Courtesy of United States Department of Agriculture

FIG. 233.—Undrained wet land in the United States, 1919

Courtesy of United States Department of Agriculture

FIG. 234.—Vegetables on a drained marsh of the South Atlantic Coastal Plain of the United States.



Courtesy of American Geographical Society

FIG. 235.—The Zuider Zee drainage project, The Netherlands. The four districts, now part of the Zuider Zee, to be reclaimed are shown in diagonal dashes. The remnant of sea left unreclaimed will be called Yssel Lake, and will be connected with the North Sea by a lock at the end of the Main Dike. The Main Dike will hold back the waters of the North Sea.

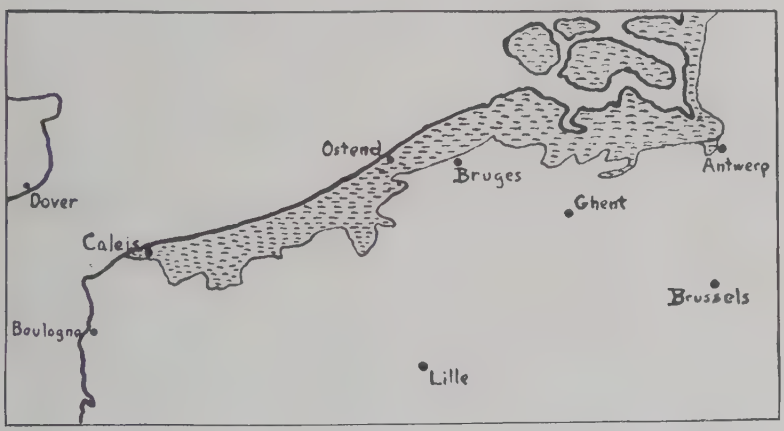


FIG. 236.—Part of the Low Countries, showing the polder land (shaded). A narrow strip of sand dunes separates the polders from the sea. (After a map by Blanchard in the *Geographical Review*, published by the American Geographical Society of New York.)

W. D. J.

FIG. 237.—Sand dune advancing upon a forest near Sawyer, Michigan; eastern shore of Lake Michigan.

Courtesy of United States Department of Agriculture

FIG. 238.—Planting beach grass to hold dunes on Cape Cod, Massachusetts

W. D. J.

Fig. 239.—An alluvial plain at the head of Kagoshima Bay, Kyushyu, Japan. Part of the land has been reclaimed from the sea, and the work of drainage is still going on.

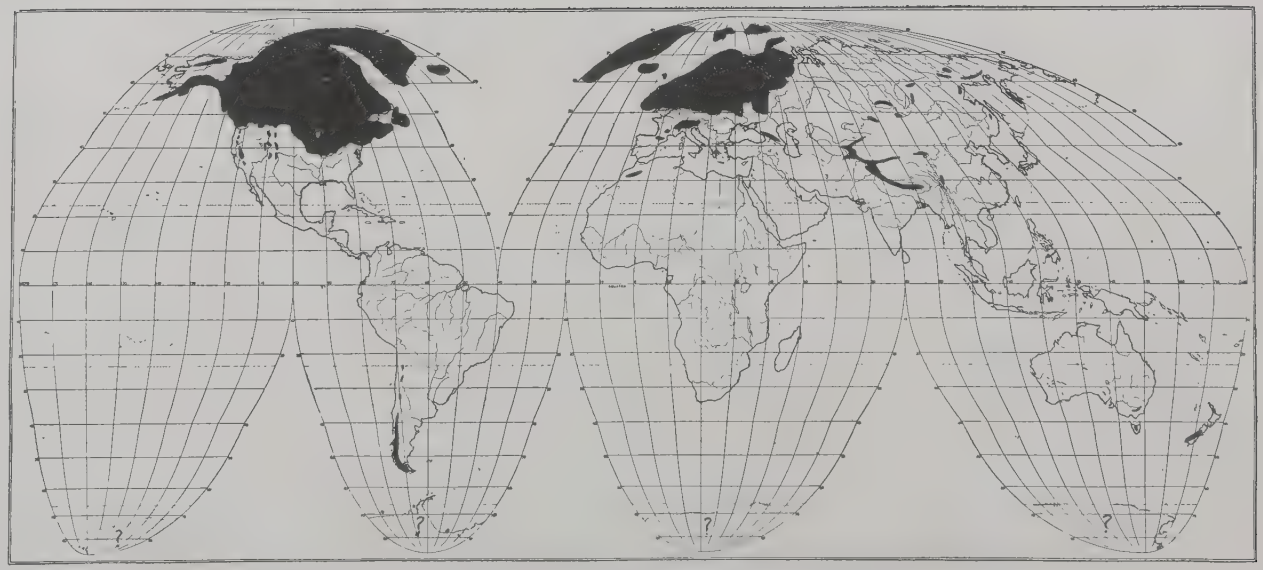


FIG. 240.—Areas glaciated so recently as to affect their utilization

After Tanton and others

FIG. 241.—Ice-scoured areas of Northeastern North America. The areas in Northern Michigan and in New England are not so extensive as shown on the map. (Adapted from a map published in the *Geographical Review* of the American Geographical Society of New York.)

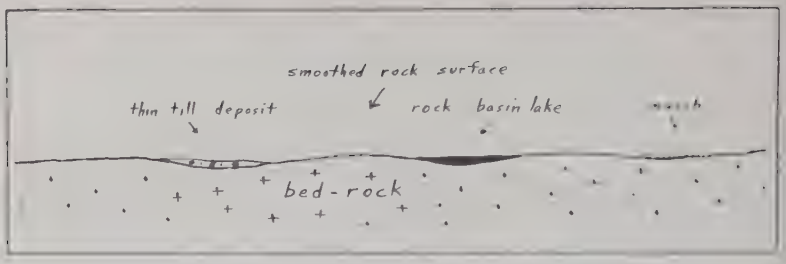


FIG. 242.—Diagrammatic cross-section of an ice-scoured plain

Courtesy of Swift and Company

FIG. 243.—Characteristic features of the southern part of the ice-scoured region of Northeastern North America.

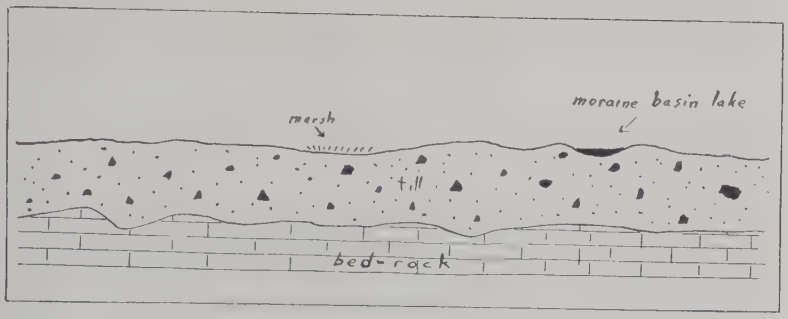


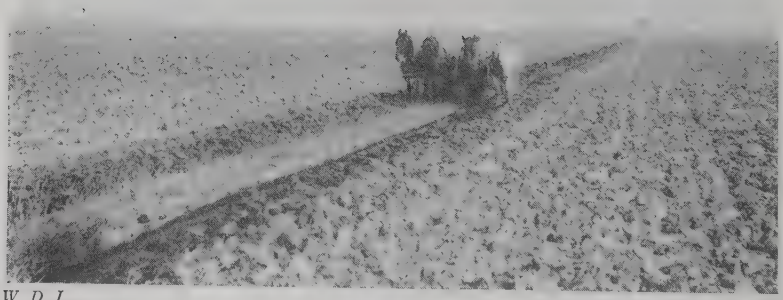
FIG. 244.—Diagrammatic cross-section of a moraine plain

W. D. J.

FIG. 245.—An exposed face of glacial till, a score of miles east of Lago Nahuel Huapi, Argentina.

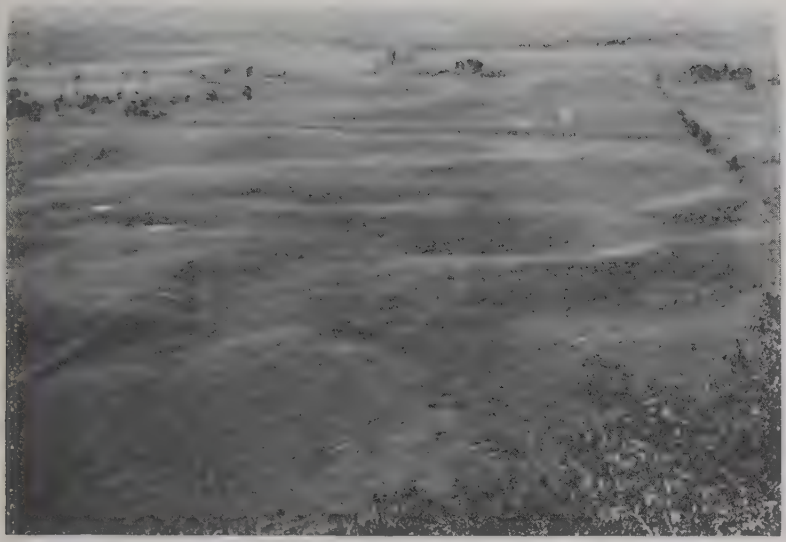
W. D. J.

FIG. 246.—Moderately rolling farmed moraine. Southern Wisconsin



W. D. J.

FIG. 247.—Plowing flat moraine plain in Northeastern Illinois



Courtesy of United States Geological Survey

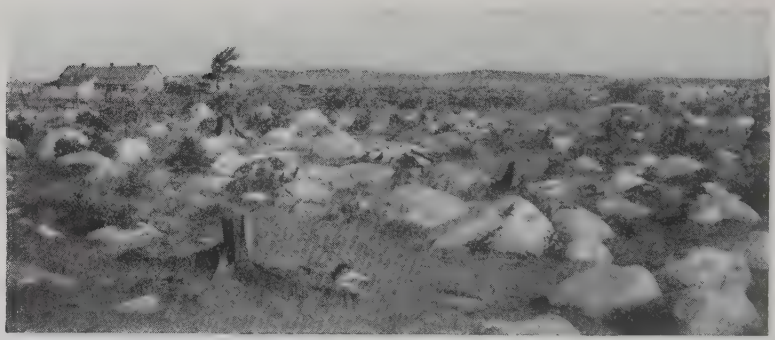
FIG. 248.—Moderately rolling moraine area with many depressions. Southern Wisconsin.

W. D. J.

FIG. 249.—Rough moraine in a farming district. Mount Forest, near Chicago, Illinois.

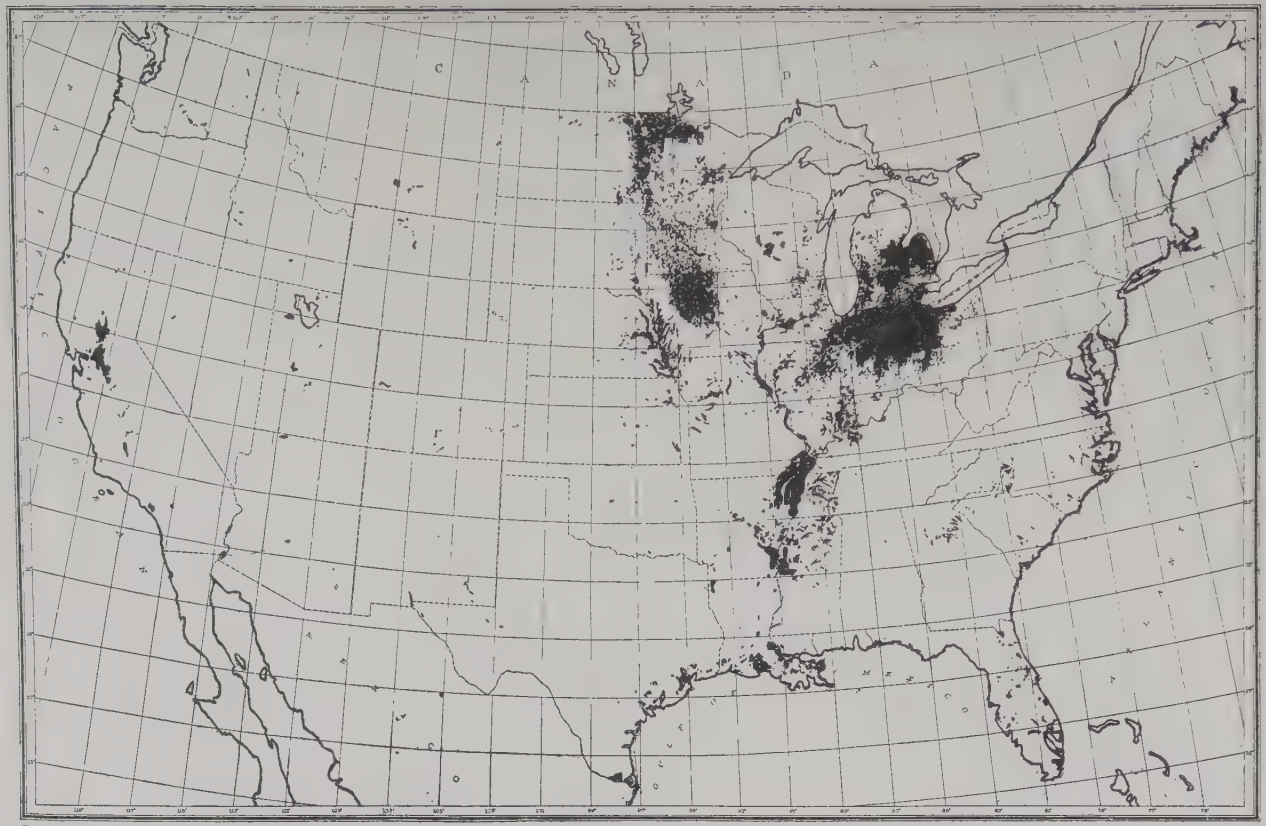
W. D J.

FIG. 250.—Gullied farm land in moraine country, Northeastern Iowa



Courtesy of American Geographical Society—Van Cleef

FIG. 251.—A bowlder-strewn moraine plain, near Chisholm, Minnesota. (From the *Geological Review*, published by the American Geographical Society of New York.)



Courtesy of United States Census Bureau

FIG. 252.—Land in the United States artificially drained, 1919

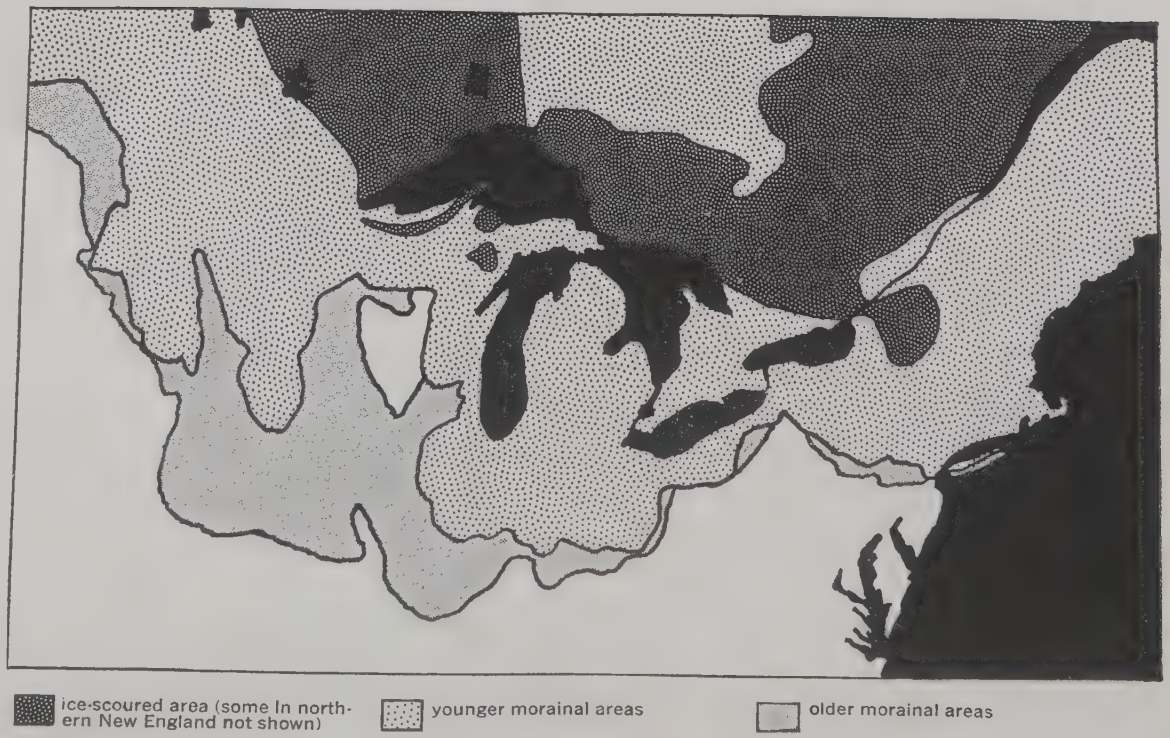
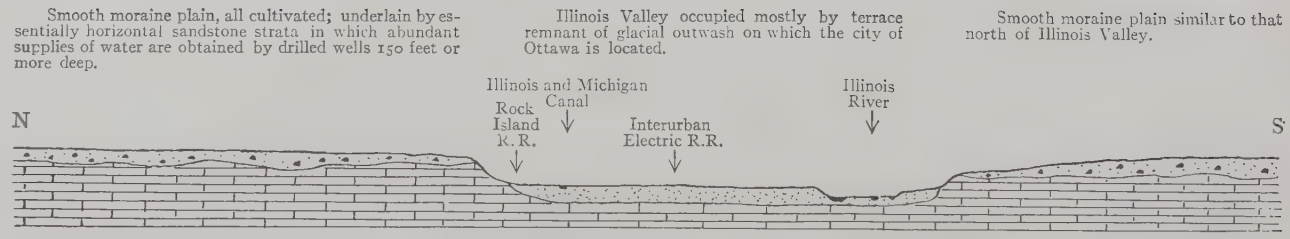


FIG. 253.—Ice-scoured, younger morainal, and older morainal areas in East Central North America. This map should be compared with an atlas relief map of the area.

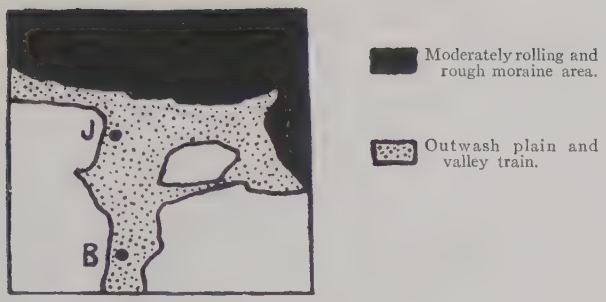
After United States Geological Survey

FIG. 254.—Deposits of glacial outwash in Middle Western United States. The continuous black line through Wisconsin, Illinois, Indiana, and Ohio shows the southern limit of the area of typical and distinctive moraine topography. Compare this map with Figure 253.


Smooth moraine plain, all cultivated; underlain by essentially horizontal sandstone strata in which abundant supplies of water are obtained by drilled wells 150 feet or more deep.
Illinois Valley occupied mostly by terrace remnant of glacial outwash on which the city of Ottawa is located.
Smooth moraine plain similar to that north of Illinois Valley.
N
Illinois and Michigan Canal
Rock Island R.R.
Interurban Electric R.R.
Illinois River
S

Width of cross-section $4\frac{3}{4}$ miles. Vertical exaggeration five times

FIG. 255.—Cross-section of the Illinois Valley through Ottawa, Illinois. This cross-section should be compared with the Ottawa, Illinois topographic map.



After Alden, United States Geological Survey

FIG. 256.—Glacial outwash in Southern Wisconsin and Northern Illinois. The cities of Janesville and Beloit are indicated by letters.

W. D. J.

FIG. 257.—Beds of stratified sand and gravel in glacial outwash near Sauk, Wisconsin.

W. D. J.

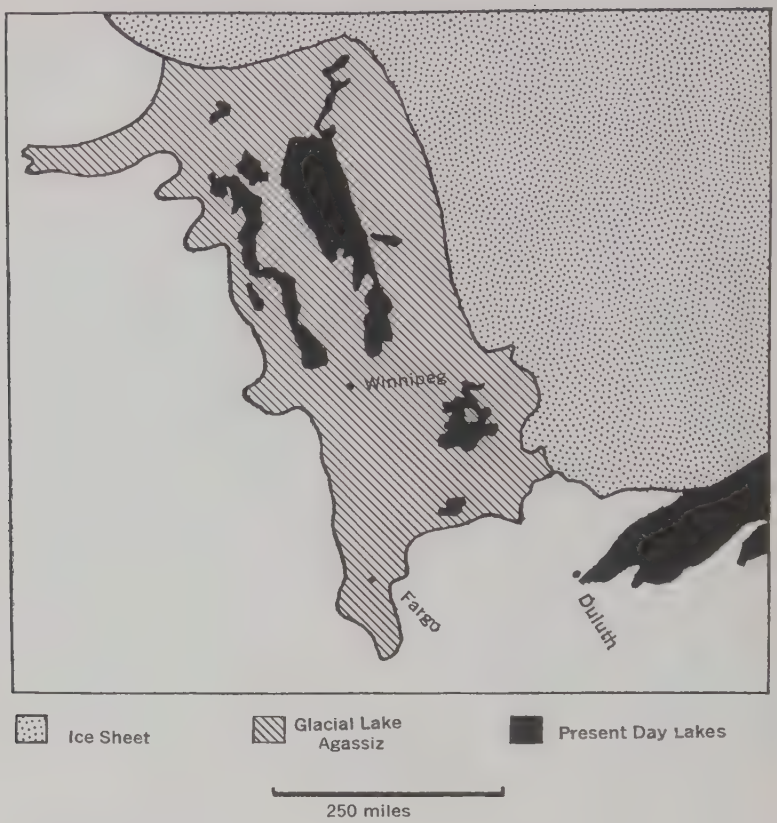
FIG. 258.—A city located on a river terrace. Heidelberg on the Neckar, Southwestern Germany.

Courtesy of International Harvester Company

FIG. 259.—Plowing on the Lake Agassiz Plain

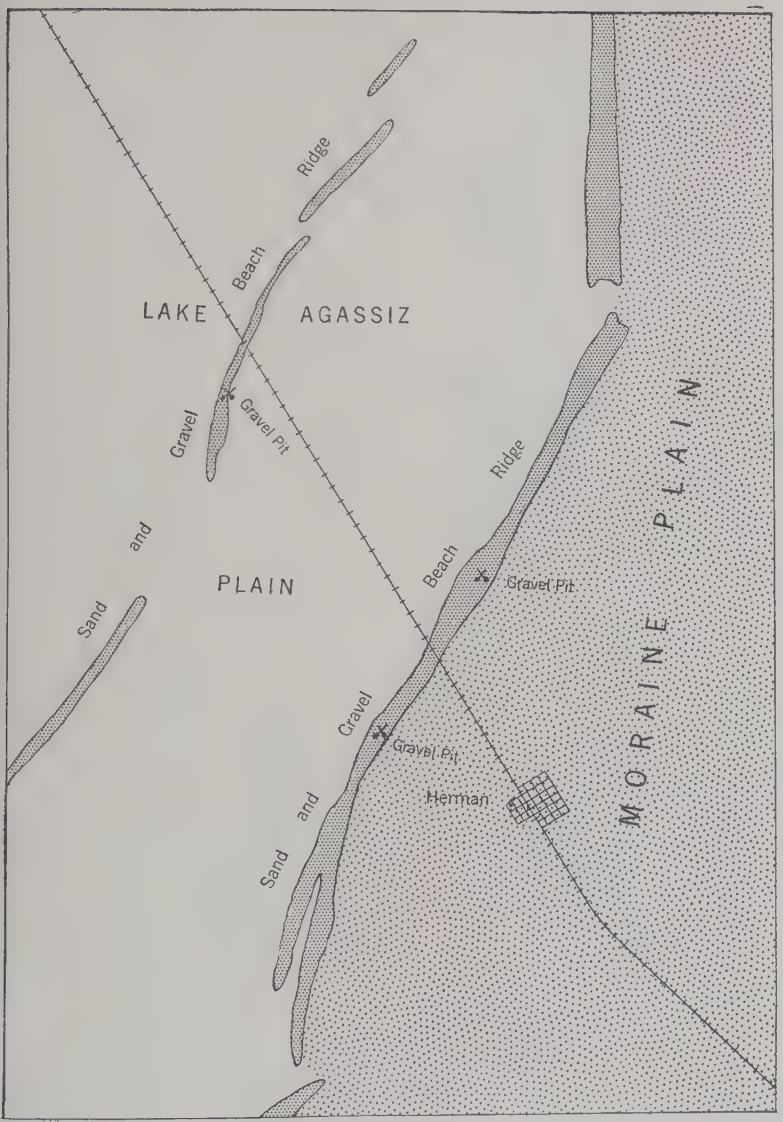
W. D. J.

FIG. 260.—A railroad on the Lake Agassiz Plain. Wheat elevators, such as that in the picture, are the most conspicuous features of the landscape.



After United States Geological Survey

FIG. 261.—The area covered by glacial Lake Agassiz. The outlet of the lake was to the south. The lake largely disappeared with the melting and disappearance of the ice sheet which formed the northern and eastern rim of the lake basin. The old lake floor constitutes a lacustrine plain of great fertility.

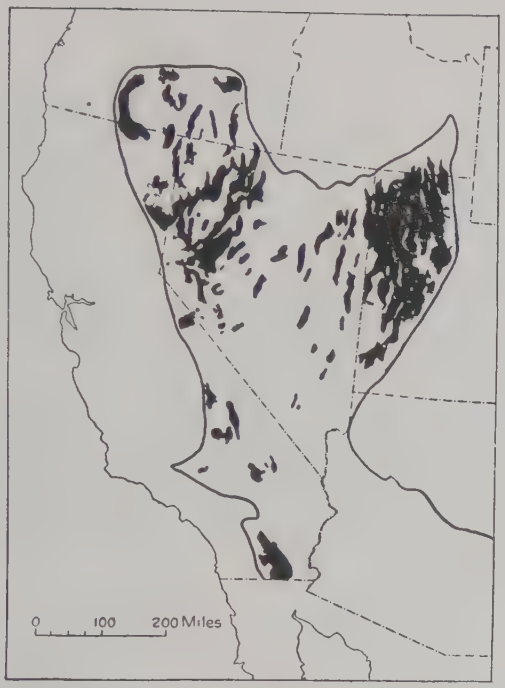


After United States Geological Survey

FIG. 262.—Surface materials at the edge of the Lake Agassiz Plain. This map should be compared with the Herman, Minnesota, topographic map of the United States Geological Survey.

After Leverett, Taylor, and others

FIG. 263.—Glacial lacustrine plains bordering the Great Lakes

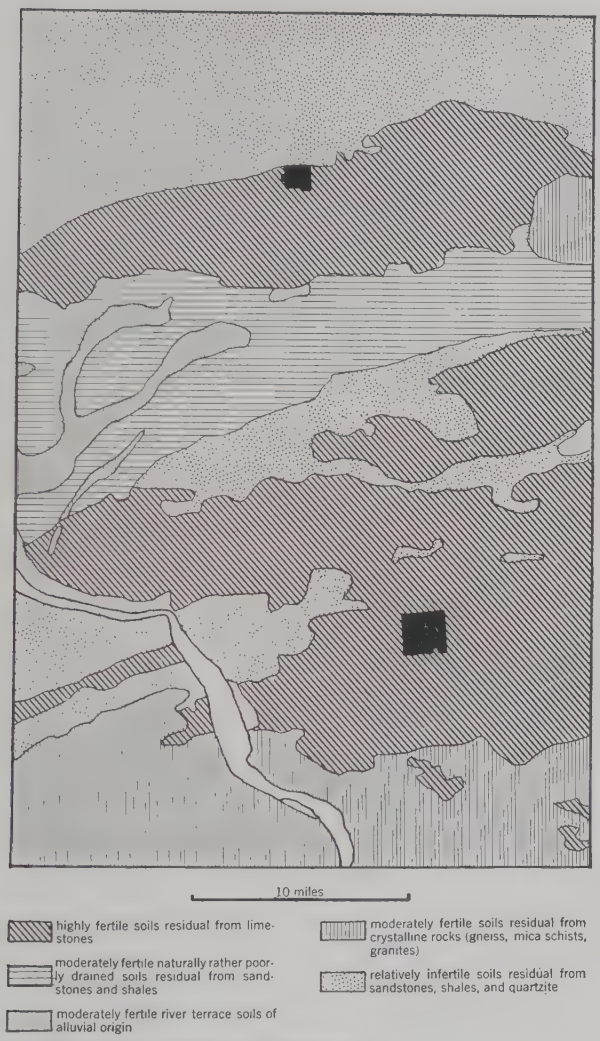


Courtesy of United States Geological Survey

FIG. 264.—The principal lacustrine plains of the Great Basin, Western United States.

Courtesy of Lancaster Chamber of Commerce

FIG. 265.—The fertile, highly cultivated plain of residual soils near Lancaster, Southeastern Pennsylvania.


10 miles
highly fertile soils residual from limestones
moderately fertile naturally rather poorly drained soils residual from sandstones and shales
moderately fertile river terrace soils of alluvial origin
moderately fertile soils residual from crystalline rocks (gneiss, mica schists, granites)
relatively infertile soils residual from sandstones, shales, and quartzite

After United States Department of Agriculture

FIG. 266.—Soil map of Lancaster–Lebanon, Pennsylvania, area. The towns of Lancaster and Lebanon are shown in solid black. This map should be compared with the Lancaster and Lebanon topographic maps.

Courtesy of Charles C. Colby

FIG. 267.—A farmstead in the Piedmont area of residual soils, south of Washington, D.C.

Courtesy of D. H. Davis

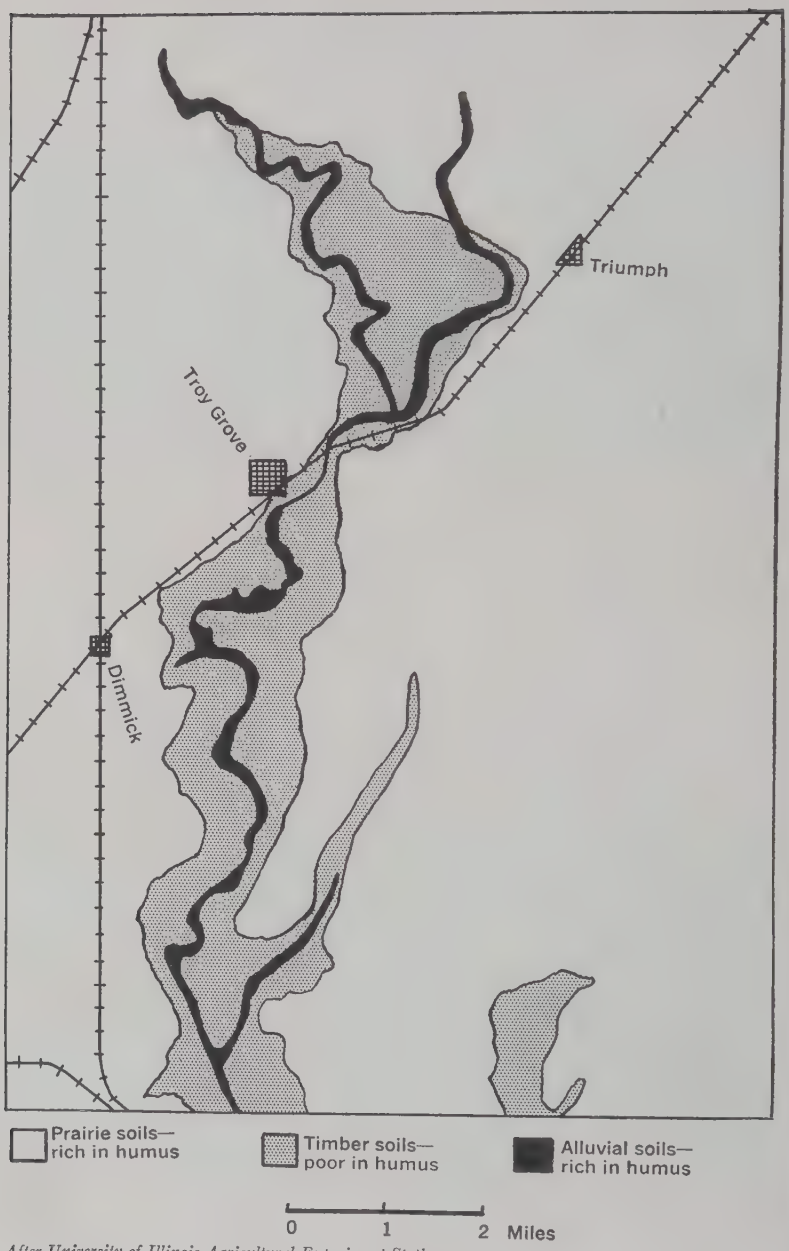
FIG. 268.—The Bluegrass of Kentucky. Note the numerous fenced horse paddocks.

W. D. J.

FIG. 269.—Thin residual soil showing outcrops of bedrock. The Valley of East Tennessee.

W. D. J.

FIG. 270.—Farm land destroyed by gullying. The Valley of East Tennessee



After University of Illinois Agricultural Experiment Station

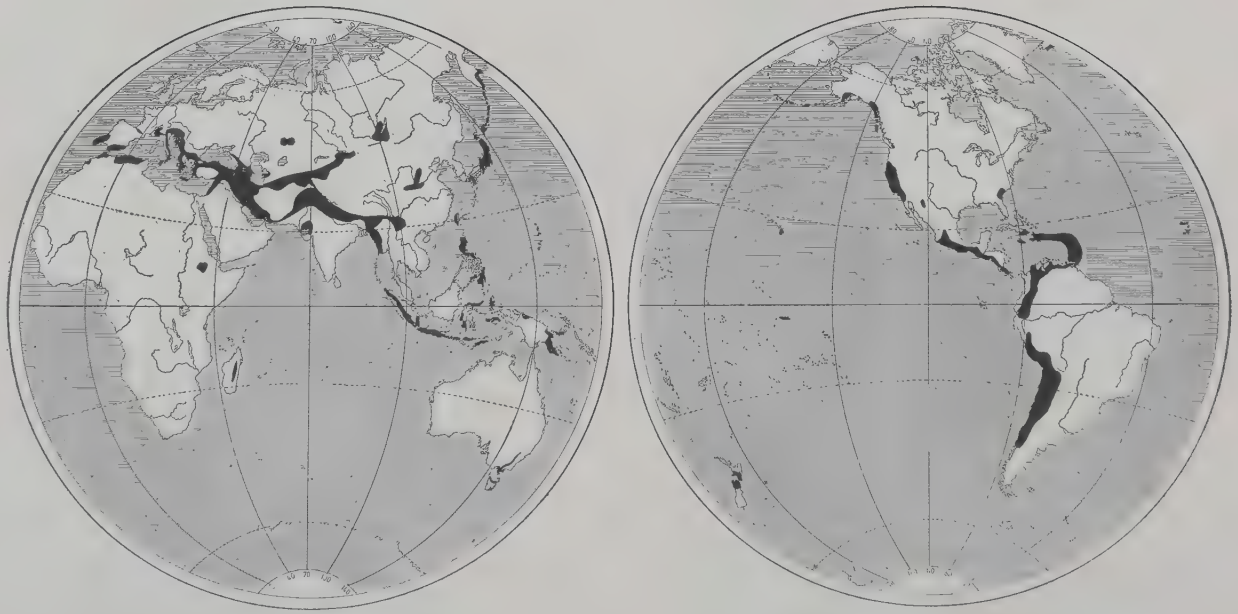
FIG. 271.—Soils of a district on the moraine plain about Troy Grove, nine miles north of La Salle, Illinois. Compare this map with the La Salle, Illinois, topographic sheet.

Courtesy of American Geographical Society

FIG. 272.—The ruined church of Cerro del Carmen, Guatemala City, after the earthquake of June, 1918. (From the *Geographical Review*, published by the American Geographical Society of New York.)

International Newsreel

FIG. 273.—Destruction wrought by the earthquake of September, 1923, at Tokyo, Japan. Modern steel construction buildings only partly destroyed.



Courtesy of de Montessus de Ballore

FIG. 274.—Areas on the continents subject to recurrent earthquakes

Courtesy of Carnegie Institution

FIG. 275.—Railroad tracks twisted by the San Francisco earthquake of 1906

Courtesy of Charles A. Beard

FIG. 276.—Part of the city of Tokyo, Japan, devastated by the earthquake of September, 1923.

Underwood & Underwood

FIG. 277.—The destroyed city of St. Pierre, Martinique, after the eruption of Mount Pelée in 1902.

W. D. J.

FIG. 278—Terraced fields buried under infertile ash from the volcano crater in the background. Island of Sakuragima in Kagoshima Bay, Kyushyu, Japan.

Courtesy of United States Geological Survey

FIG. 279.—Quarry in limestone, from which building blocks are being taken. Near Milwaukee, Wisconsin.

W. D. J.

FIG. 280.—Quarry in limestone near Chicago. The rock is crushed for use in roadmaking, concrete, and fertilizer.

W. D. J.

Fig. 281.—Pit-head of a coal mine in the hill country of Eastern Kentucky. The coal is mined from a shaft below the pit-head, and from hill-side tunnels reached by tracks on the trestles.

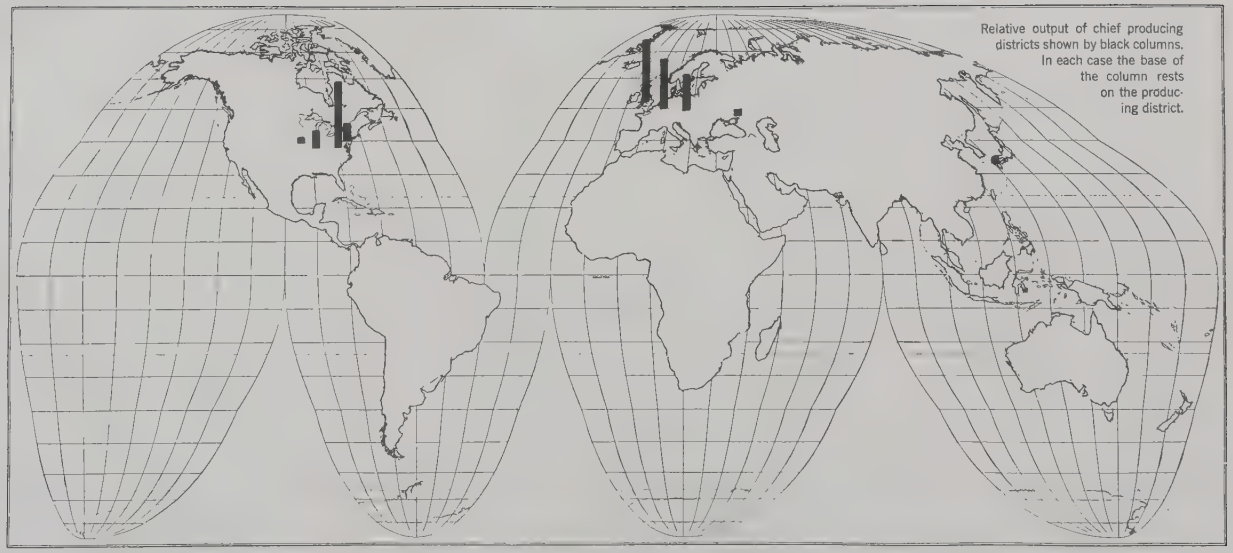
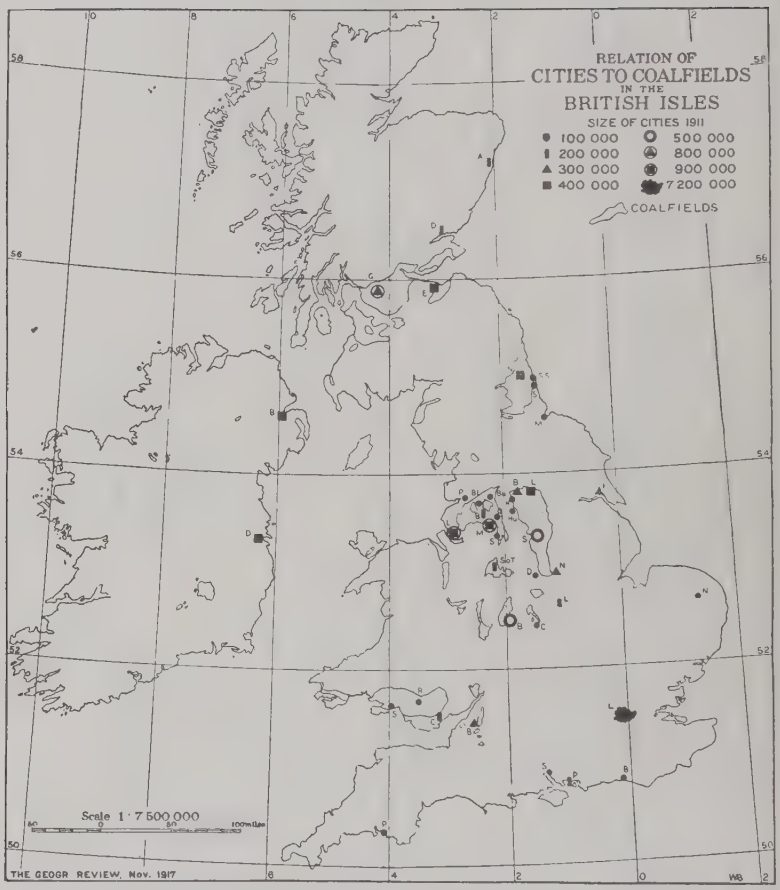

Relative output of chief producing districts shown by black columns. In each case the base of the column rests on the producing district.

FIG. 282.—Coal-producing districts of the earth

Relative output of chief producing districts shown by black columns. In each case the base of the column rests on the producing district.

FIG. 283.—Iron ore–producing districts of the earth

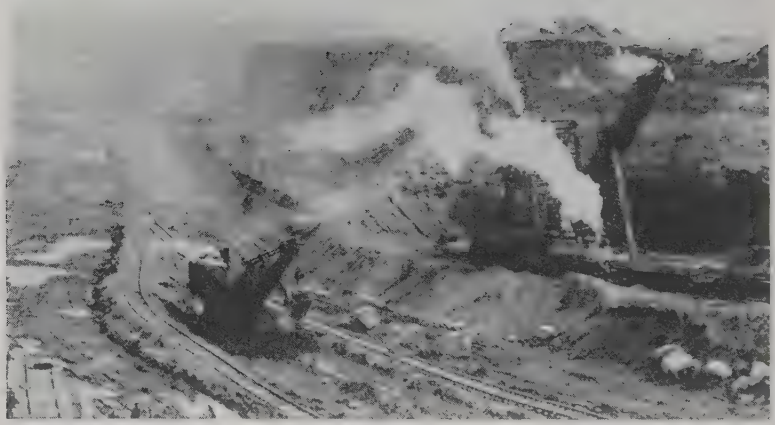


Courtesy of American Geographical Society—Mark W. Jefferson

FIG. 284.—Cities and coalfields of the British Isles. (From the *Geographical Review*, published by the American Geographical Society of New York.)

W. D. J.

FIG. 285.—Surface mining near Nagpur, India. The hill, which is composed of manganese ore, is being mined away.



Courtesy of Iron Trade Review

FIG. 286.—Stripping glacial till off iron-ore deposits at Hibbing, Minnesota. The ore will be mined in the same manner by steam shovel.

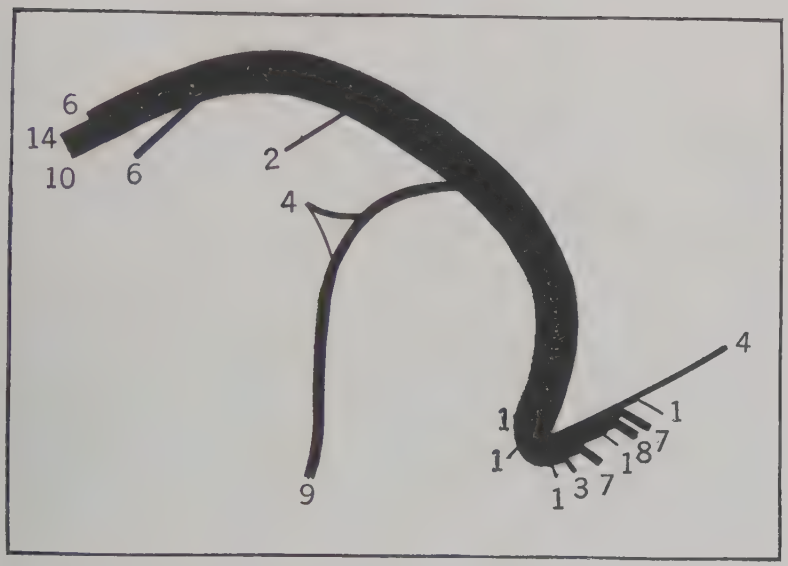
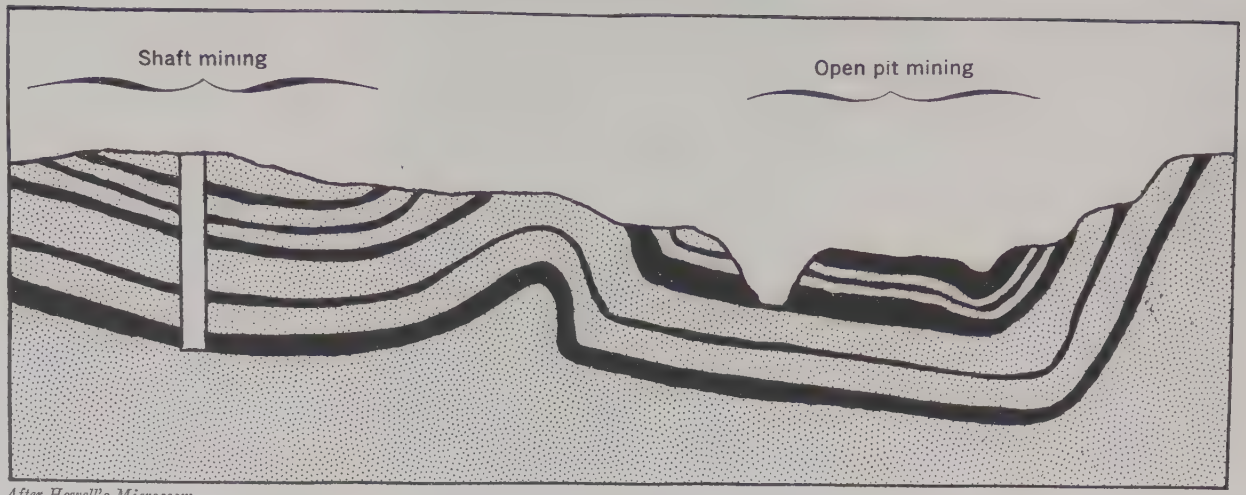


Fig. 287.—Movement of iron ore on the Great Lakes. Shipments and receipts in millions of tons are indicated by figures, as follows: *Upper Lakes shipping ports*, Two Harbors, 6; Duluth, 14; Superior, 10; Ashland, 6; Marquette, 2; Escanaba, 4. *Lower Lakes receiving ports*, South Chicago–Indiana Harbor–Gary, 9; Detroit, 1; Toledo, 1; Huron, 1; Lorain, 3; Cleveland, 7; Fairport, 1; Ashtabula, 8; Conneaut, 7; Erie, 1; Buffalo, 4. The iron mines are a few score miles inland from the shipping ports; the iron and steel mills are at the receiving ports or a few score miles inland in Eastern Ohio and Western Pennsylvania. This map should be compared with an atlas map of the Great Lakes.

Courtesy of Illinois State Geological Survey

FIG. 288.—Pit-head and spoil heap of a shaft coal mine in the farming district of Central Illinois.

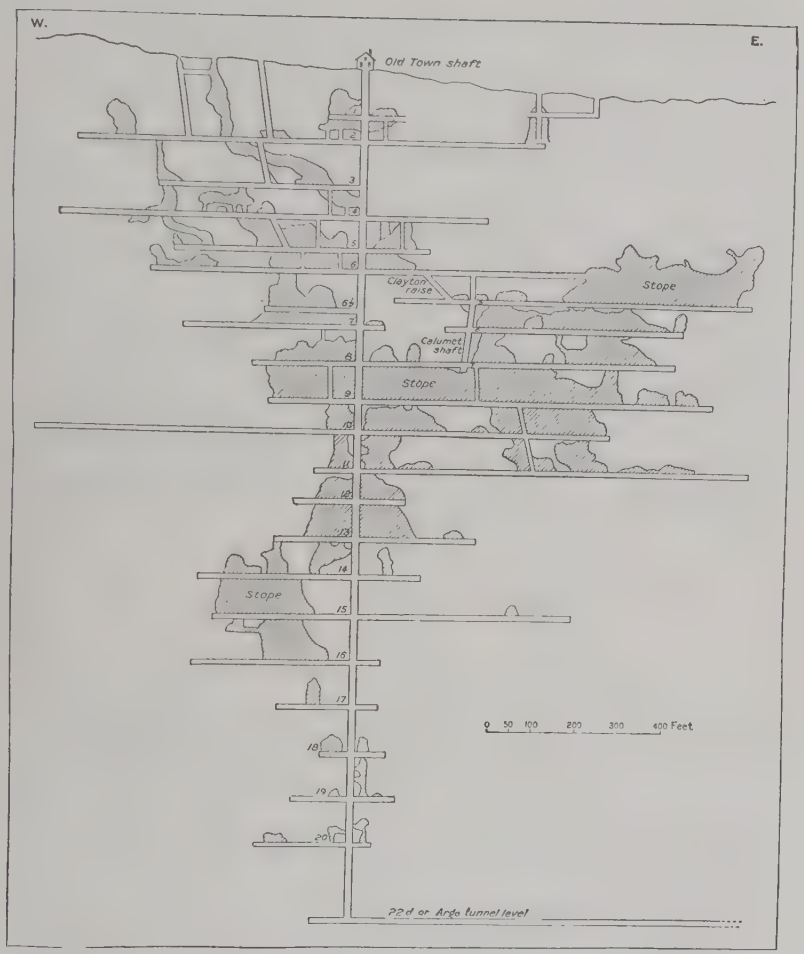


After Howell's Microcosm

FIG. 289.—Cross-section of coal seams in Pennsylvania Anthracite District, mined from shafts and galleries and in open pits

Courtesy of Southern Pacific Railroad

FIG. 290.—A mining community in the desert, Tonopah, Nevada. Silver ore is taken from deep shaft mines.



Courtesy of United States Geological Survey

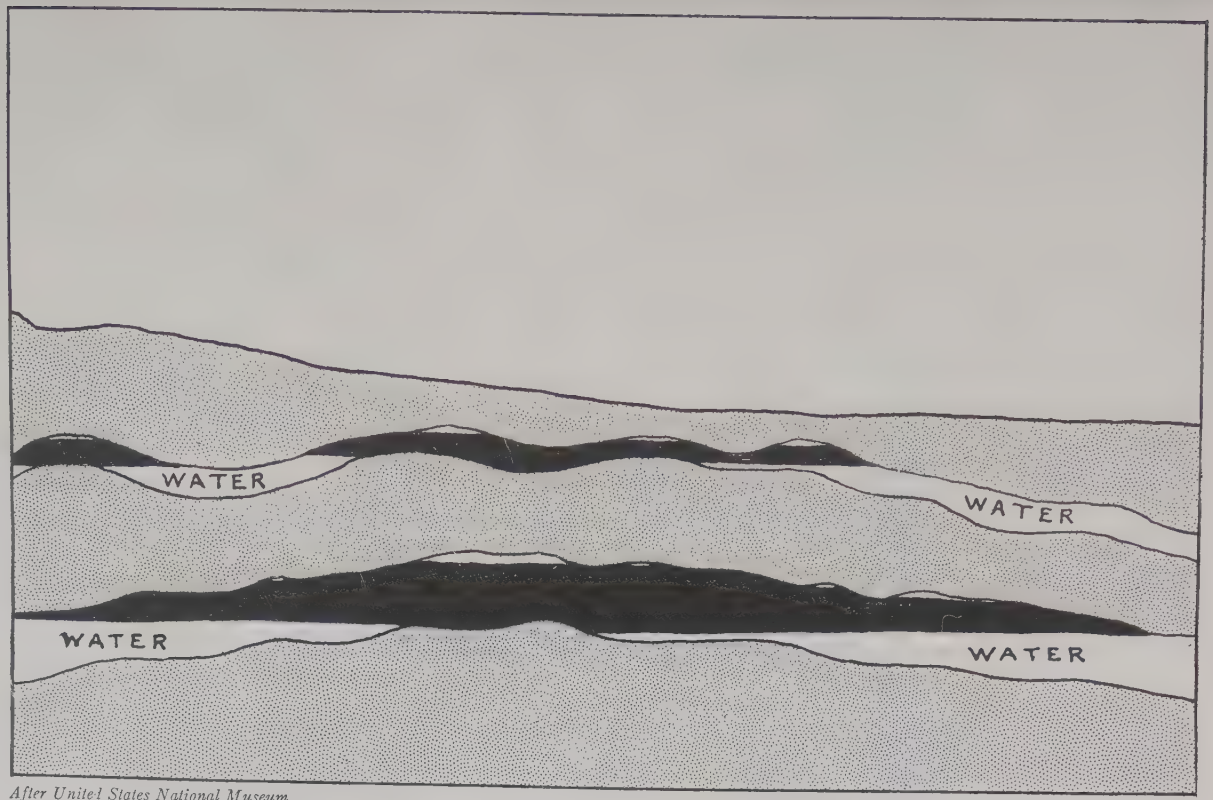
FIG. 291.—Cross-section of a gold mine about 30 miles west of Denver, Colorado. The ore occurs in a sheetlike vein which dips at an angle of about 45°. The shaft follows the slope of the vein, which is worked from horizontal tunnels at several levels. The view in this cross-section is broadside of the vein, and shows in cross-lining the areas which have been mined out.

Courtesy of United States Department of Commerce

FIG. 292.—Hydraulic mining in the Malay Peninsula. The metal sought, which is tin, occurs in river gravels.

Courtesy of H. L. Smith and F. G. Tickell

FIG. 293.—Petroleum field, Southern California

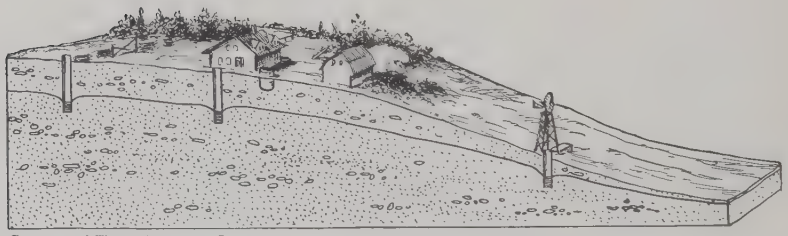


After United States National Museum

FIG. 294.—Typical occurrence of petroleum (black) and natural gas (white, overlying the oil). The strata in which the oil, gas, and water occur are relatively porous. The petroleum and gas are obtained from drilled wells; in some cases the wells flow, in other cases pumping is required.

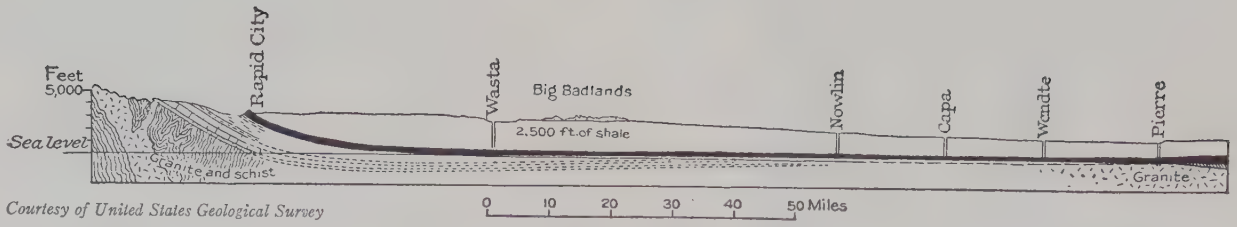
Courtesy of Henry Holt and Co.

FIG. 295.—Diagrammatic cross-section showing the relation between the surface of the earth and the ground-water surface. (From Salisbury, Barrows, and Tower, *Elements of Geography*.)



Courtesy of Henry Holt and Co.

FIG. 296.—Diagrammatic cross-section showing safe and unsafe wells. (From Salisbury, Barrows, and Tower, *Elements of Geography*.)



Courtesy of United States Geological Survey

FIG. 297.—Cross-section from the Black Hills to the Missouri River, showing artesian water conditions. The Dakota sandstone, shown in solid black, is the leading water-bearing stratum. Above the sandstone lie impervious strata of shale. Below the sandstone the cracks and pores of the rocks are filled with water, but the water-holding capacity of these rocks is much less than that of the sandstone. Rain which falls in the Black Hills and seeps into the sandstone eventually flows out of the deep drilled wells to the east.

Courtesy of United States Geological Survey

FIG. 298.—Horizon of springs, the presence of which is shown by vegetation, on the face of the bluff along the line of contact between rock strata. Columbia Plateau, Western United States.

W. D. J.

FIG. 299.—A farm in semi-arid Northern Patagonia, with fields and orchards irrigated from a hillside spring.

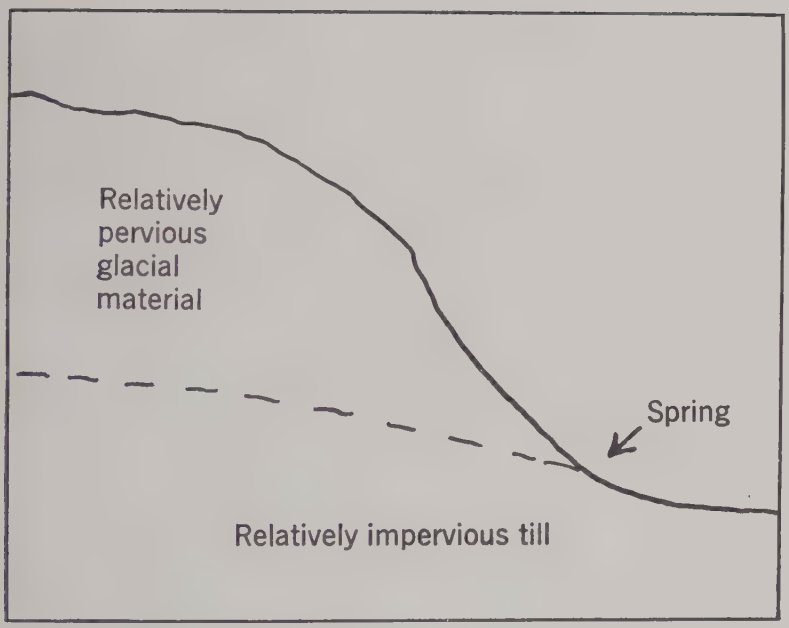
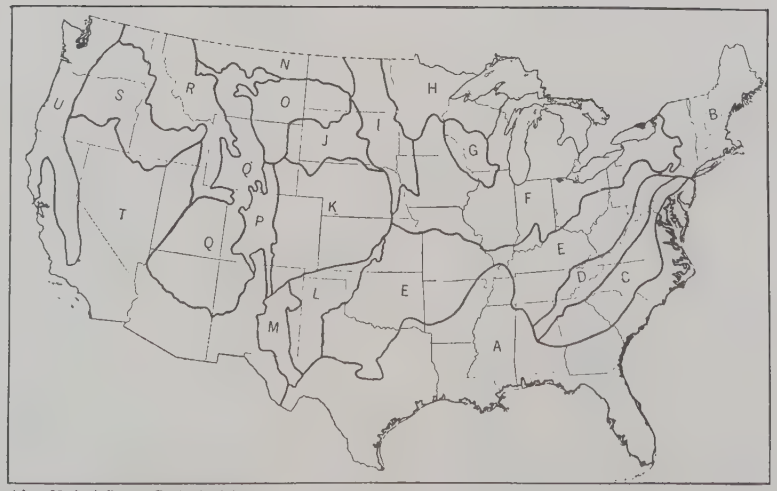


Fig. 300.—Diagrammatic cross-section of a spring at the contact between pervious and impervious glacial material.



After United States Geological Survey

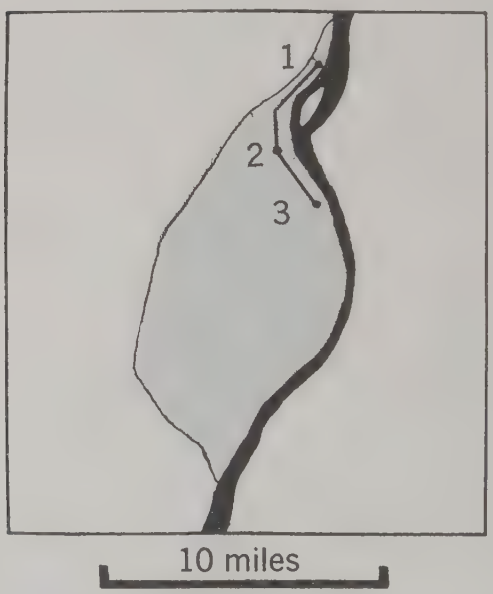
FIG. 301.—Ground-water provinces of the United States. See legend on opposite page.

LEGEND TO ACCOMPANY MAP OF GROUND-WATER PROVINCES OF THE UNITED STATES (FIG. 301)

Name of Province	Chief Source of Ground Water
A. Atlantic and Gulf Coastal Plain Province	Unconsolidated sand and gravel strata. Some artesian flow
B. Northeastern Glaciated Province	Glacial outwash and till
C. Piedmont Province	Residual soils and joints in crystalline rock
D. Appalachian Ridge and Valley Province	Springs
E. South Central Province of Older Sedimentary Rocks	Sandstone and limestone strata. Supply meager
F. North Central Glaciated Province	Glacial outwash and till. Artesian supply from underlying older sandstone strata
G. Upper Mississippi Driftless Province	Sandstone and limestone strata of older sedimentary rocks. Some artesian flow
H. Lake Superior Glaciated Province	Glacial outwash and till. Underlying and exposed crystalline rocks yield little water
I. Dakota Glaciated Province	Glacial outwash and till; an abundant artesian flow from underlying sandstone stratum
J. Black Hills Province	Supply meager except from artesian wells in deep sandstone stratum
K. Central Great Plains Province	Unconsolidated sand and gravel strata. Artesian flow from deeper sandstone stratum
L. Southern Great Plains Province	Unconsolidated sand and gravel strata
M. Trans-Pecos Province of Older Sedimentary Rocks	Sedimentary strata yield scanty and highly mineralized supplies
N. Northwestern Glaciated Province	Glacial outwash and till. Some water from underlying sedimentary rocks
O. Northern Great Plains Province	Unconsolidated sand and gravel strata
P. Southern Rocky Mountain Province	Springs
Q. Montane Plateau Province	Sedimentary rocks. Production varies greatly in quantity from place to place
R. Northern Rocky Mountain Province	Springs. Additional supplies in glacial outwash
S. Columbia Lava Plateau Province	Wells and springs supplied from lava beds
T. Southwestern Waste Filled Basin Province	Sand and gravel filling of basins between mountains
U. Pacific Mountain and Valley Province	Heavy rainfall results in abundant ground-water supplies everywhere

After San Francisco Department of Public Works

FIG. 302.—The water-supply system of San Francisco, California. This map should be compared with an atlas relief map.



After St. Louis Board of Public Service

FIG. 303.—Water-supply system of St. Louis, Missouri. River water is taken from the Mississippi at point 1, where sediment is settled and the water is filtered. It then flows through conduits to the pumping stations at 2 and 3, whence it is distributed to the city through mains. The sewers of the city empty into the river *below* the island shown on the map. The boundary of the municipality has been extended up stream to include the water intakes and supply conduits.

Courtesy of San Francisco Department of Public Works

FIG. 304.—Reservoir of the San Francisco water system, Hetch Hetchy Valley, Sierra Nevada Mountains

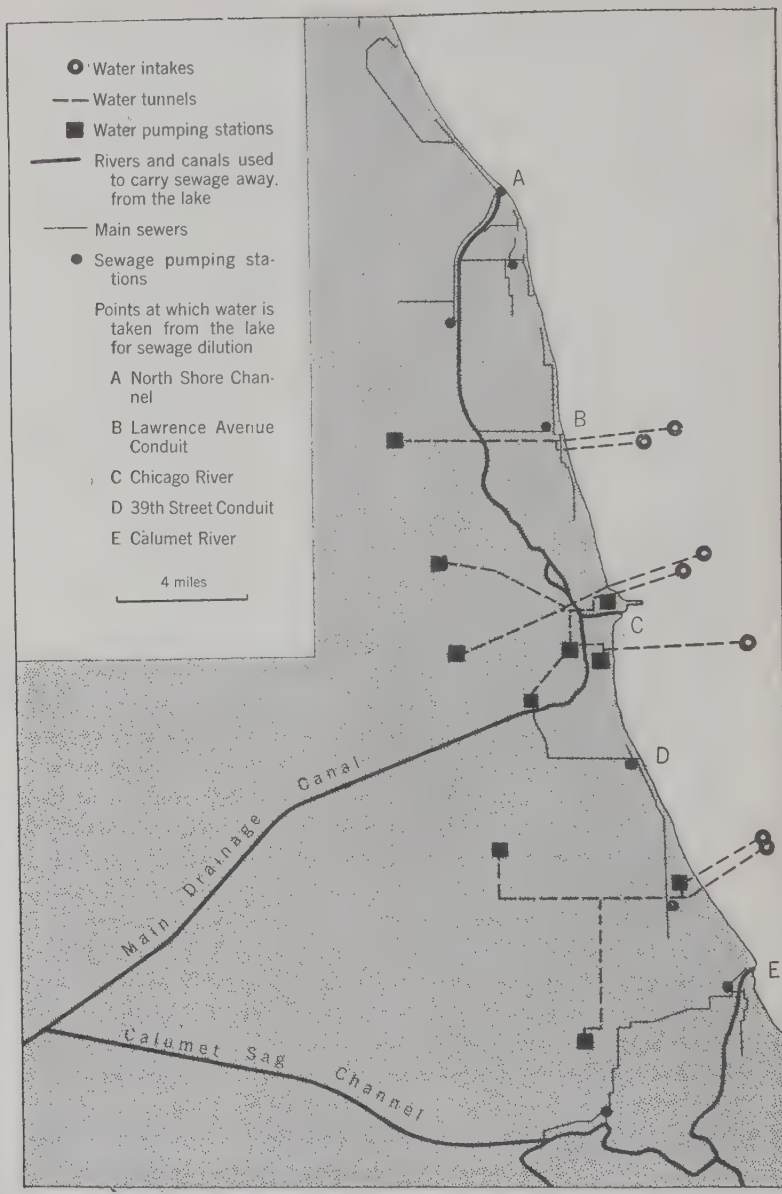
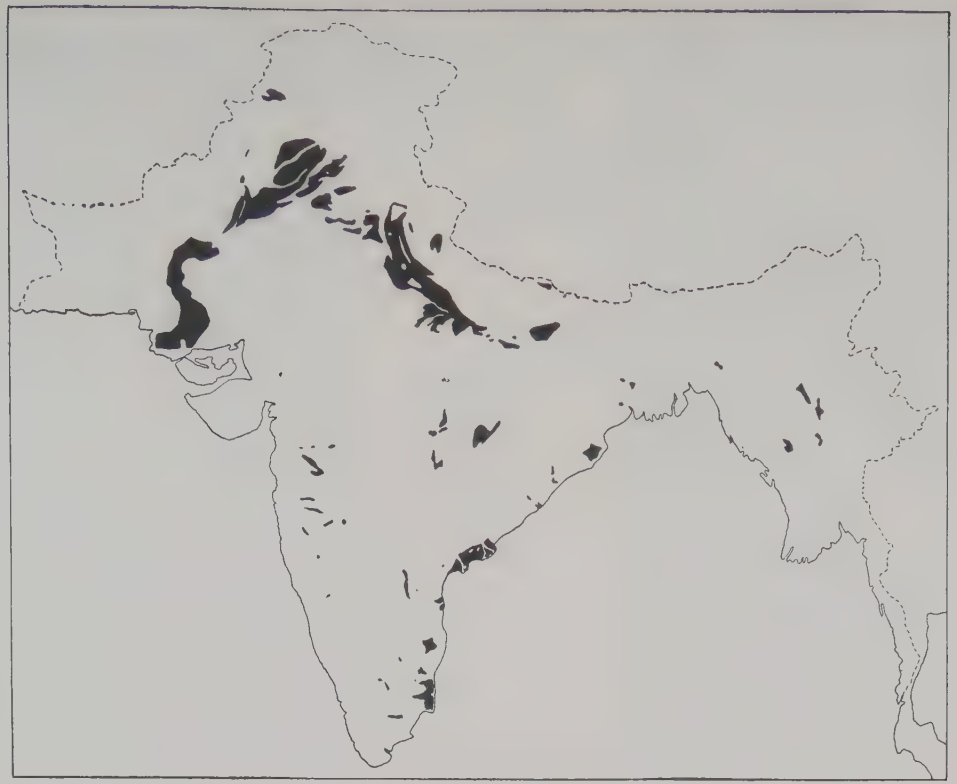


FIG. 305.—The water-supply and sewage-disposal systems of Chicago, Illinois. This map should be compared with the topographic maps of the area.



After Public Works Department, Government of India

FIG. 306.—The chief areas irrigated from canals in India, 1920

W. D. J.

Fig. 307.—Hand irrigation from a well on the Ganges Plain, near Cawnpore, India.

W. D. J.

Fig. 308.—The Ganges River at the front of the Himalayas and the diversion works of the Upper Ganges Canal.

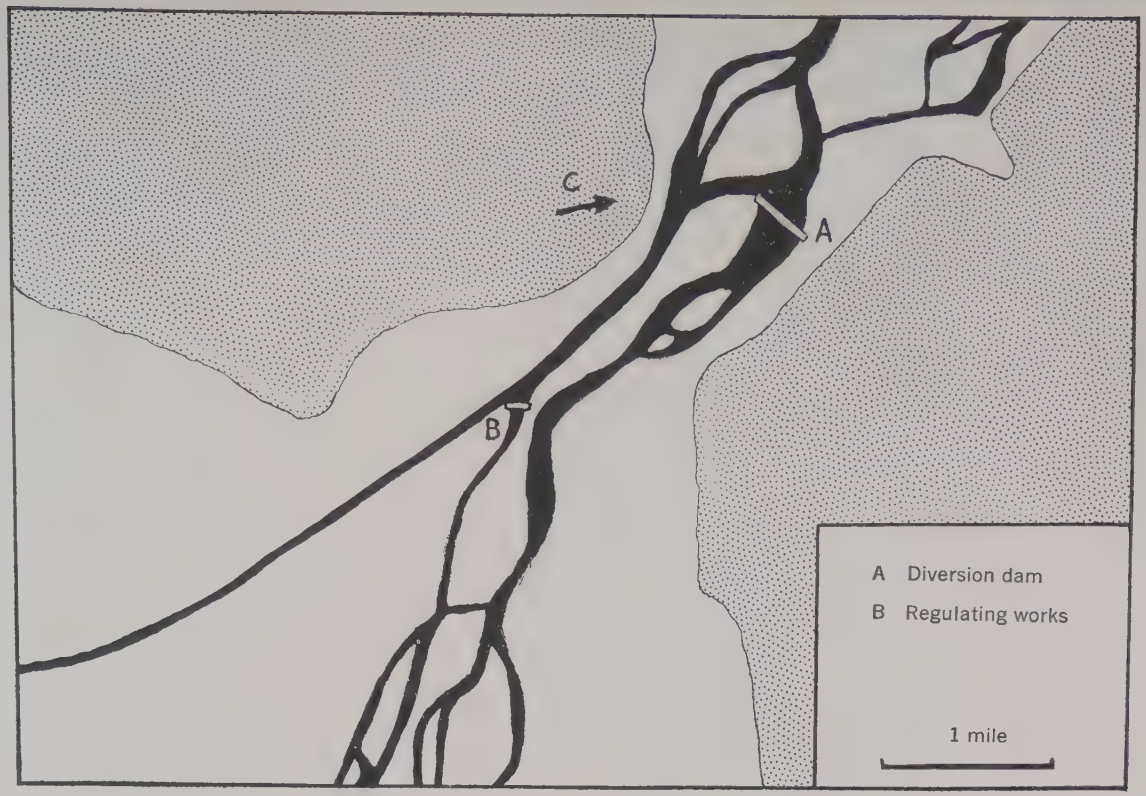
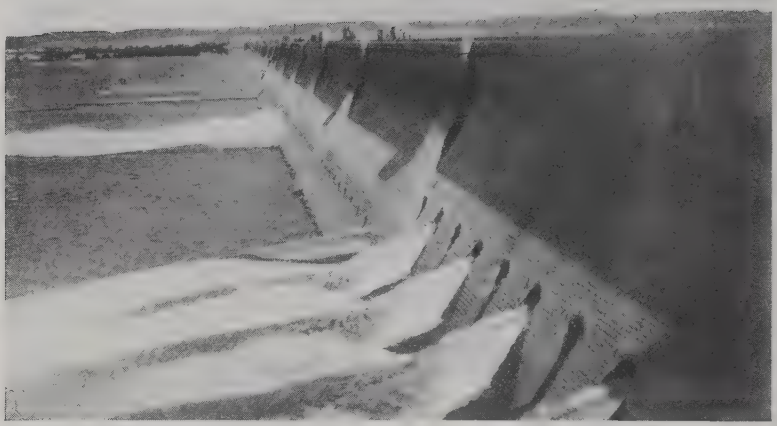


FIG. 309.—Diversion works of the Upper Ganges Canal. See Figure 308, which shows the works viewed from point *C*.

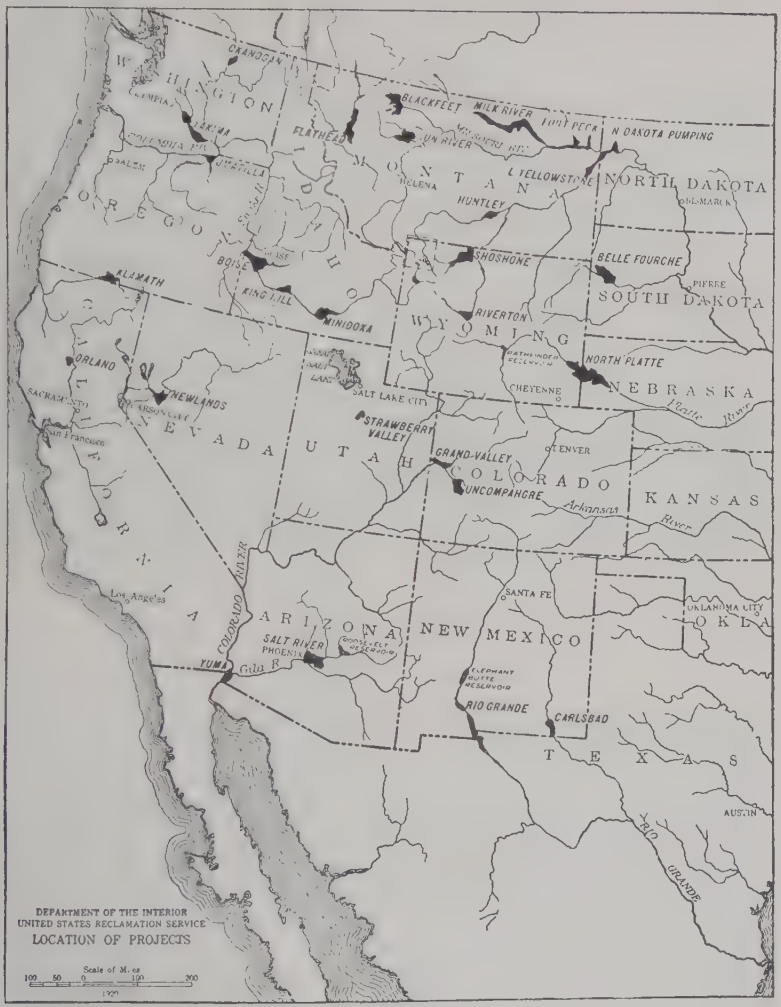


Courtesy of Ministry of Public Works, Egypt

FIG. 310.—The Aswan Dam on the Nile River, Egypt

Courtesy of United States Reclamation Service

FIG. 311.—Irrigation canal lined with concrete. Newlands Project, Nevada



Courtesy of United States Reclamation Service

FIG. 312.—United States Government irrigation projects

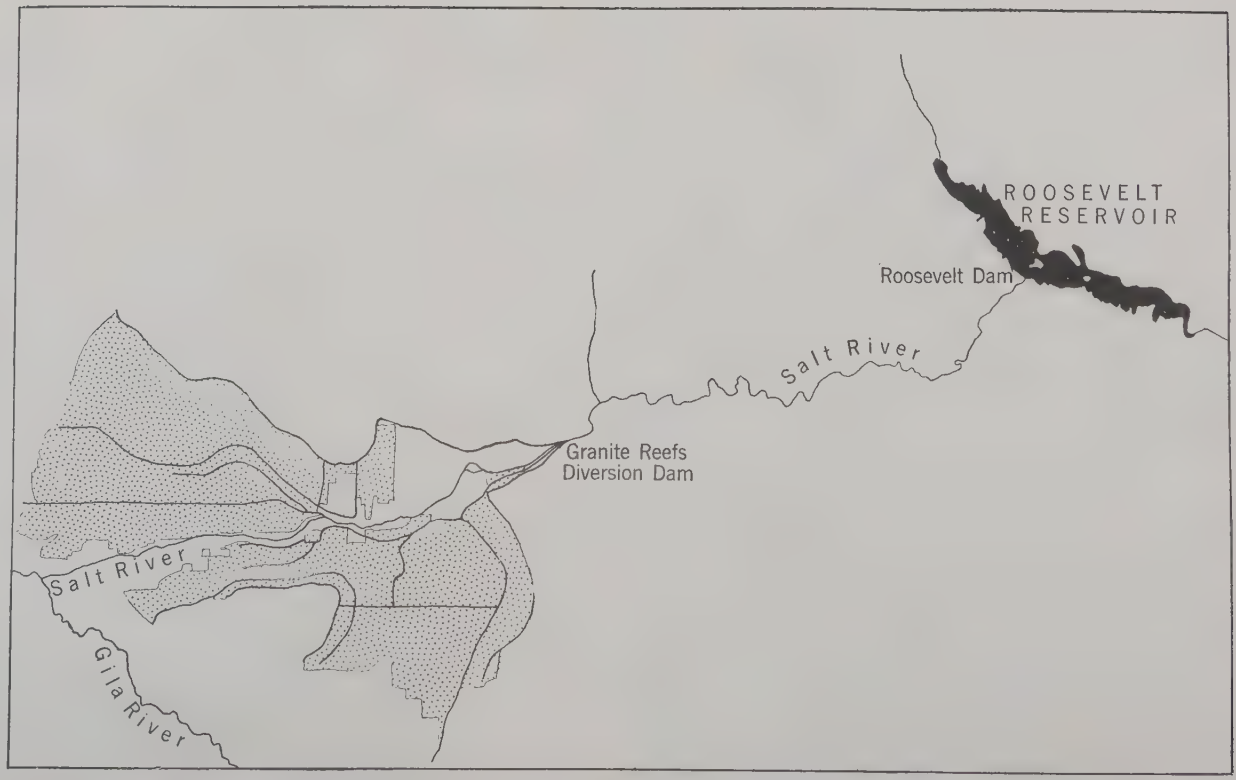


Fig. 313.—The Salt River Reclamation Project, Arizona. Irrigated area shown in stipple. Major canals shown by smooth black lines.

Courtesy of United States Reclamation Service

FIG. 314.—Roosevelt Dam, Salt River Reclamation Project, Arizona

Courtesy of United States Reclamation Service

FIG. 315.—Irrigating a field, Uncompahgre Reclamation Project, Western Colorado.

Courtesy of United States Reclamation Service

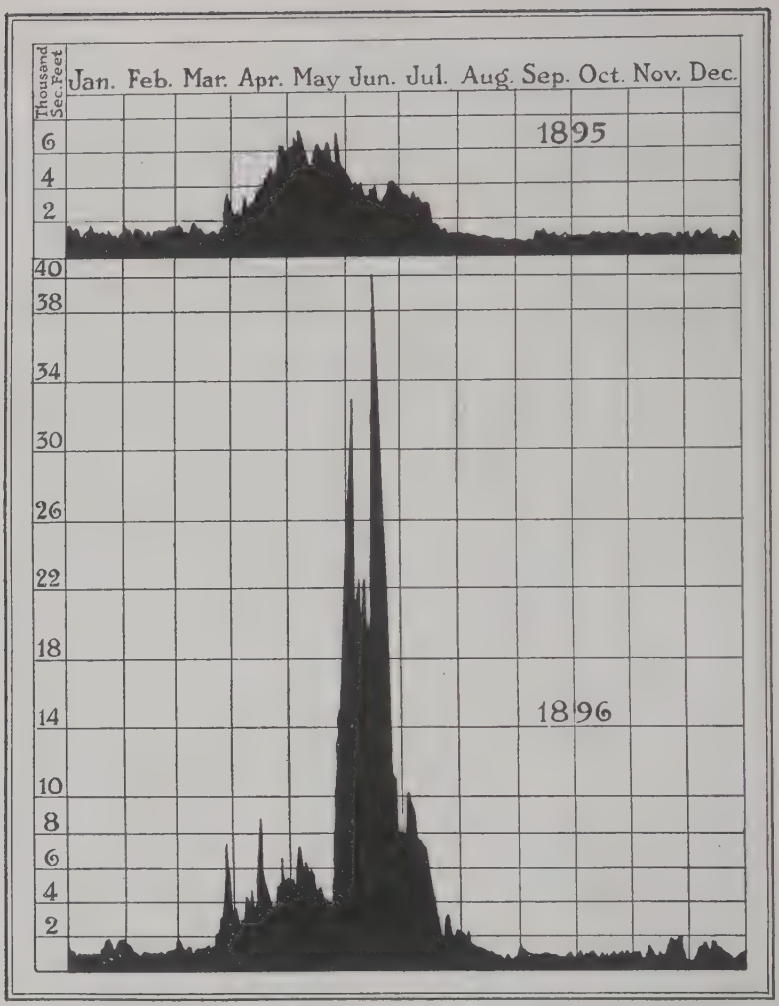
FIG. 316.—Diversion dam and canal, Strawberry Valley Reclamation Project, Utah.

Courtesy of United States Reclamation Service

FIG. 317.—Pumping plant to lift water from a canal at river level (middle background) to a high-level canal (right foreground). Grand Valley Reclamation Project, Western Colorado.

Courtesy of United States Reclamation Service

FIG. 318.—Irrigation canal high up on the side of a valley, Yakima Project, Washington.



Courtesy of United States Geological Survey

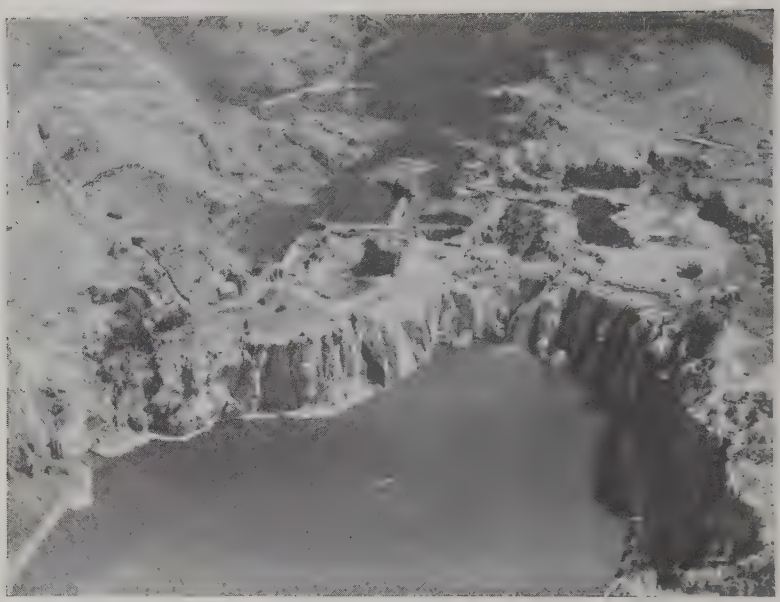
FIG. 319.—Variations in the volume of flow of the Boise River, above Boise, Idaho, from January, 1895, to December, 1896.

W. D. J.

FIG. 320.—A typical mountain stream in the rainy Southern Andes of Chile. latitude 40° S.

Courtesy of General Electric Company

FIG. 321.—Hydroelectric plant at Long Lake, Washington



Courtesy of United States Army Air Service

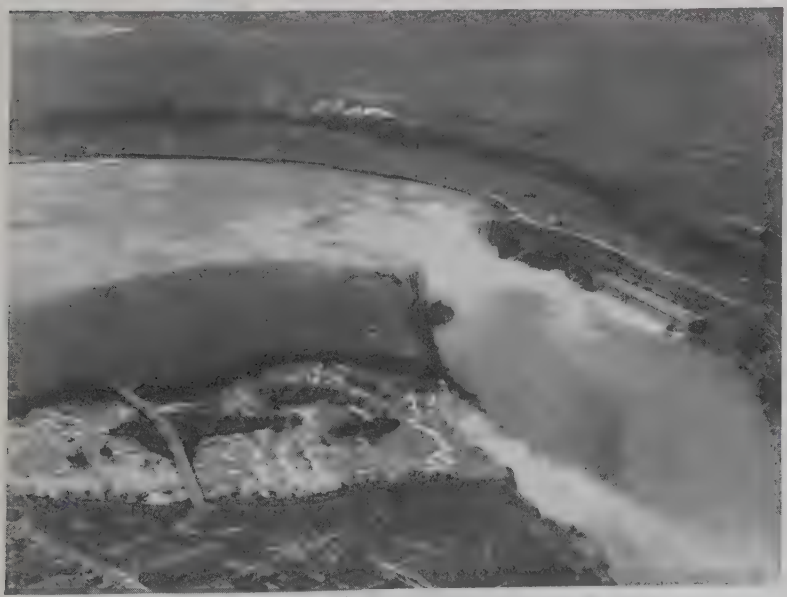
FIG. 322.—Hydroelectric power development at Shoshone Falls, Idaho. Powerhouse at lower left.

Courtesy of Mississippi River Power Company

FIG. 323.—Hydroelectric plant at the Des Moines Rapids on the Mississippi River, Keokuk, Iowa.

Courtesy of Chicago, Milwaukee, and St. Paul Railroad

FIG. 324.—Hydroelectric power applied to railroad transportation in the mountains of Western United States.



Courtesy of the United States Army Air Service

FIG. 325.—Niagara Falls, with a part of its hydroelectric development. Powerhouse below Falls at right.

W. D. J.

FIG. 326.—A Mississippi River steamboat. Below Davenport, Iowa

W. D. J.

FIG. 327.—Grain elevator and warehouse, built and much used during the days of active Mississippi River commerce. Prairie-du-Chien, Wisconsin.

W. D. J.

FIG. 328.—A large junk, used in the Yangtse River trade

W. D. J.

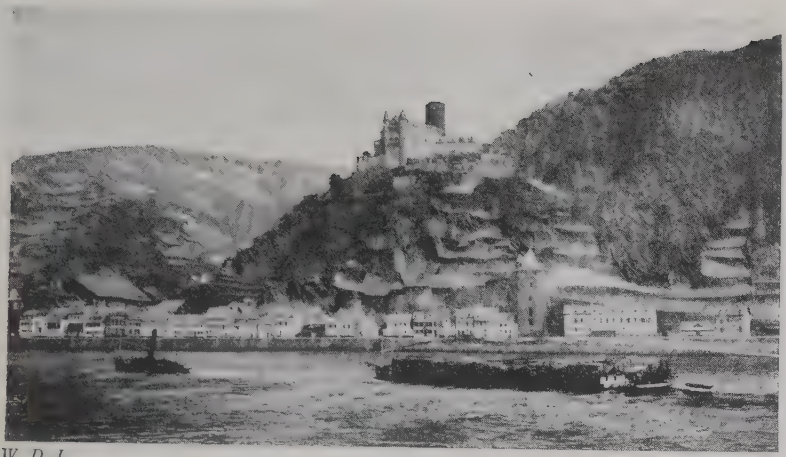
FIG. 329.—The river front at Canton, China, a typical delta city

W. D. J.

FIG. 330.—Shipping at the confluence of the Han and Yangtze rivers, Hankow, China.

W. D. J.

FIG. 331.—Men towing a boat through the rapids at the lower end of the gorges of the Pei River, South China. Downstream from these rapids there is a thriving commercial town.

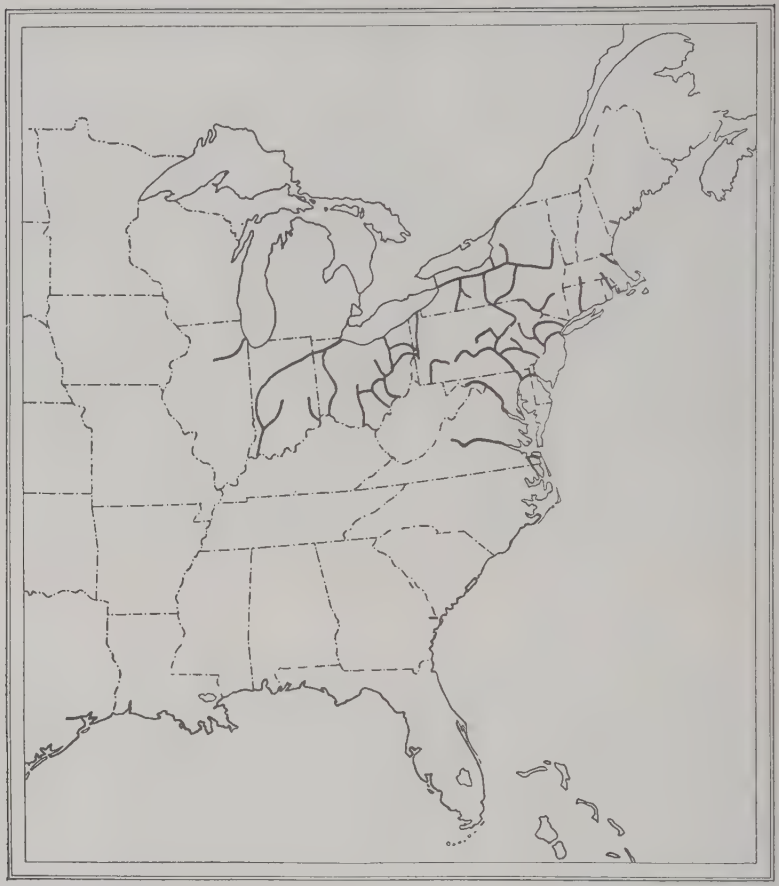


W. D. J.

FIG. 332.—Barge traffic on the Rhine above Coblenz

W. D. J.

FIG. 333.—Log rafts on the Kushiro River at Kushiro Hokkaido, Japan



Courtesy of Henry Holt and Co.

FIG. 334.—Principal canals constructed in the United States before 1875. (From Salisbury, Barrows, and Tower, *Elements of Geography*.)

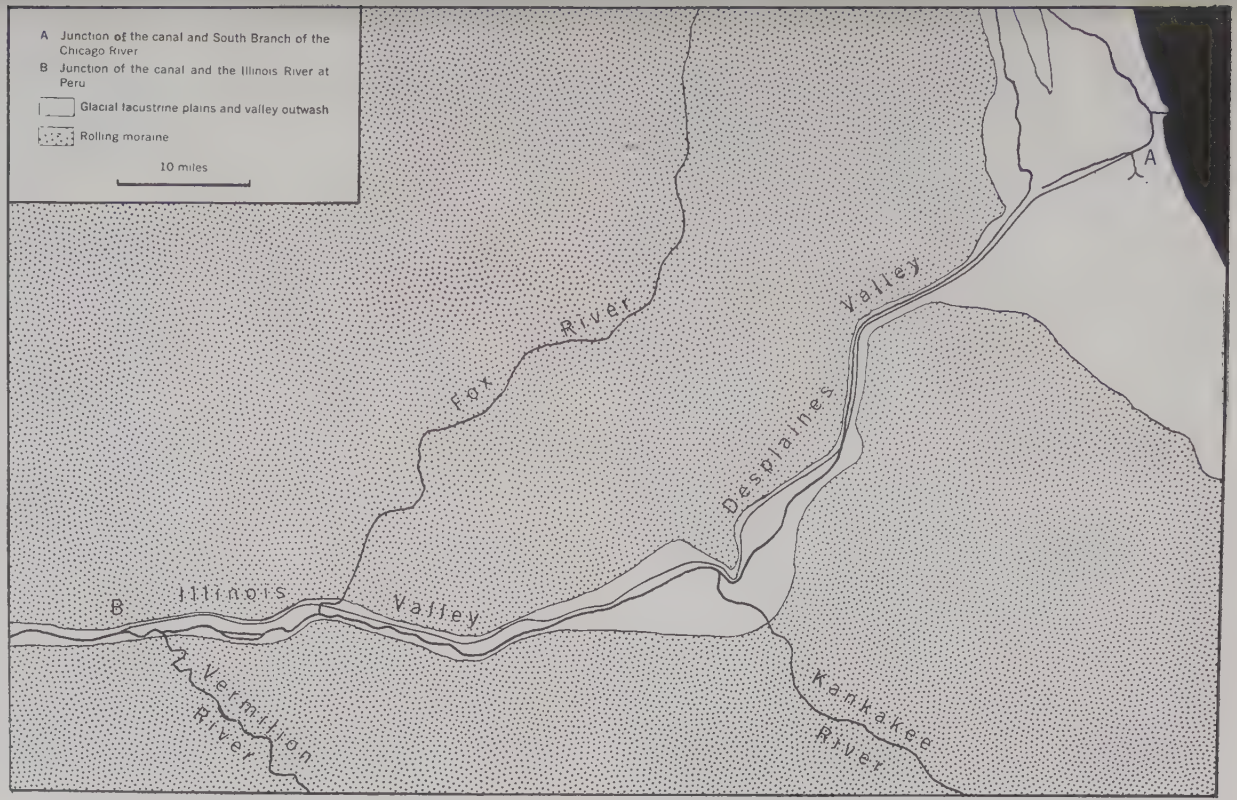
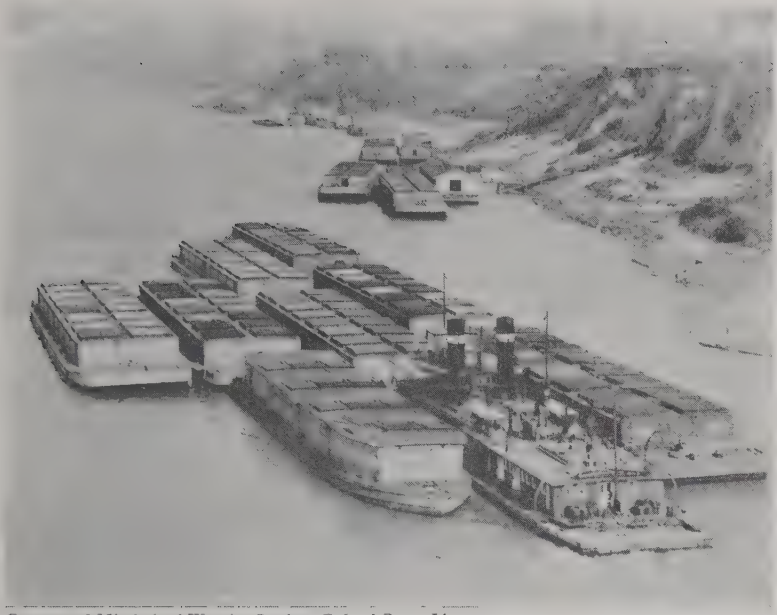


FIG. 335.—The Illinois Michigan Canal (shown by the fine black line extending from *A* to *B*). The canal lies on the south side of the Desplaines Valley north and east of Joliet; at Joliet it crosses the river and to the south and west lies on the north side of the valley.

W. D. J.

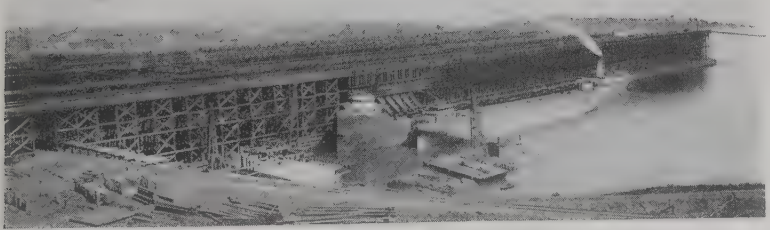
FIG. 336.—Lock on the Illinois and Michigan Canal

FIG. 337.—Principal canals and navigable rivers in North Central Europe. Important river cities indicated by initials.



Courtesy of Mississippi Warrior Service—Federal Barge Line

FIG. 338.—A fleet of modern barges on the Mississippi River at Memphis, Tennessee.



Courtesy of Illinois Steel Corporation

FIG. 339.—Steamer loading at ore docks at Duluth, Minnesota. Iron ore is carried by trains on to the docks and dropped into bins below the tracks. From these bins the ore slides down chutes into the holds of the large lake freighters.

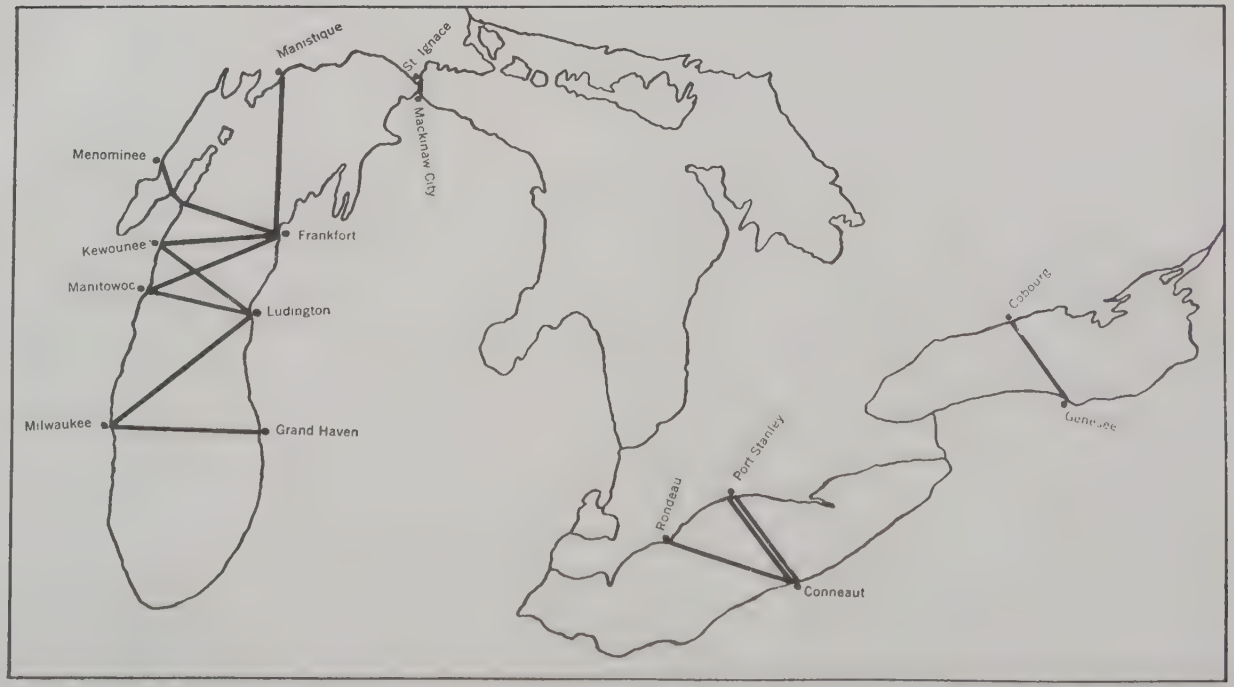
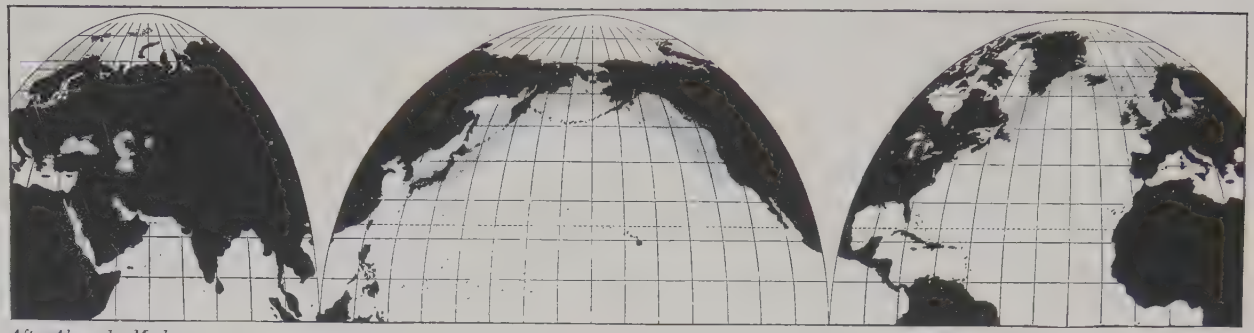
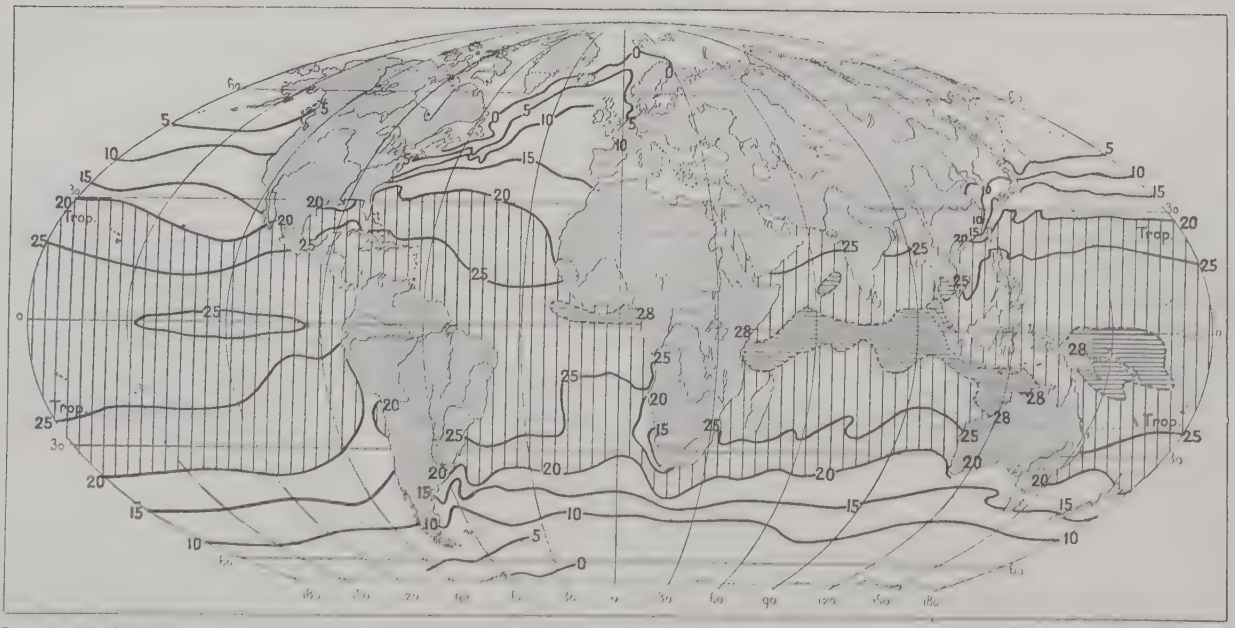


FIG. 340.—Car-ferry lines crossing the Great Lakes



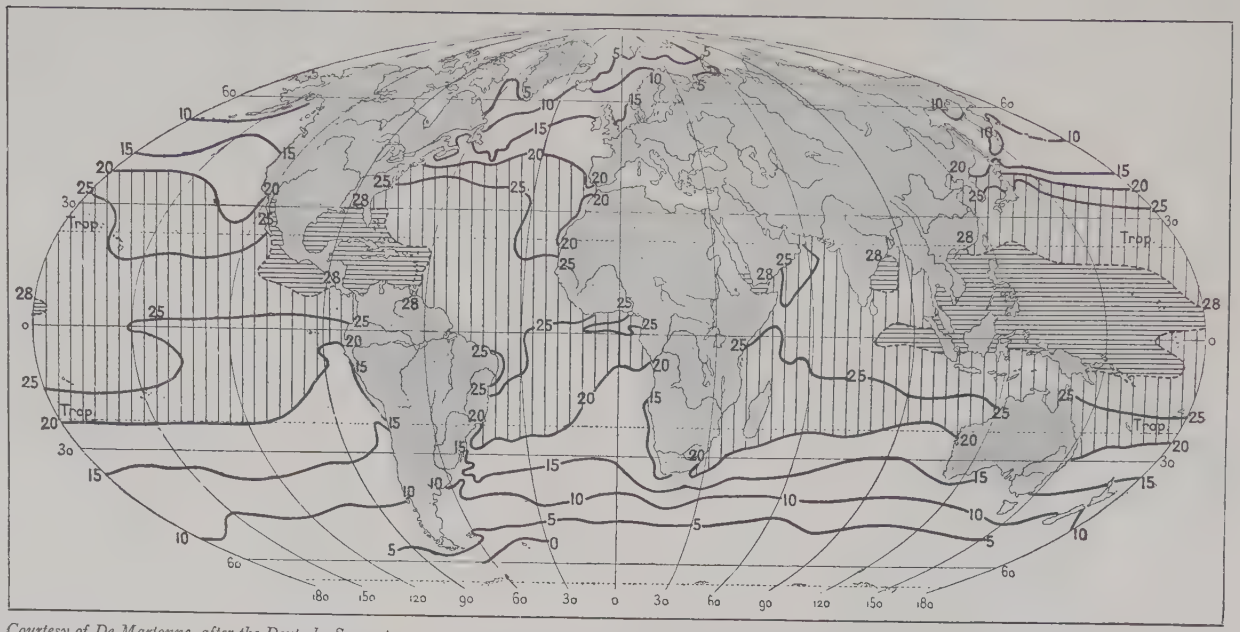
After Alexander Meek

FIG. 341.—Distribution of herring (genus Clupea). Herring areas shown in stipple.



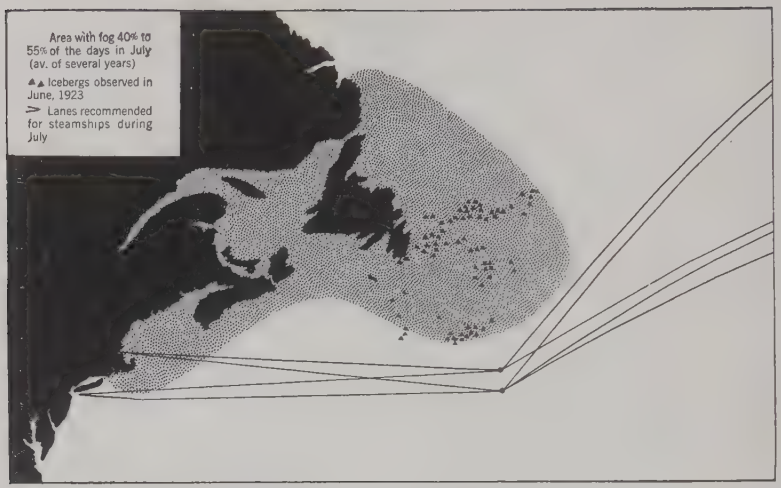
Courtesy of De Marlonne, after the Deutsche Seewarte

FIG. 342.—Surface water temperatures of the oceans for February. Monthly average in degrees Centigrade



Courtesy of De Martonne, after the Deutsche Seewarte

FIG. 343.—Surface-water temperatures of the oceans for August. Monthly average in degrees Centigrade


Area with fog 40% to 55% of the days in July (av. of several years)
Icebergs observed in June, 1923
Lanes recommended for steamships during July

After Hydrographic Office, United States Navy

FIG. 344.—Map of fog and icebergs in early summer near North Atlantic steamship lanes. Fog infested area shown in stipple.

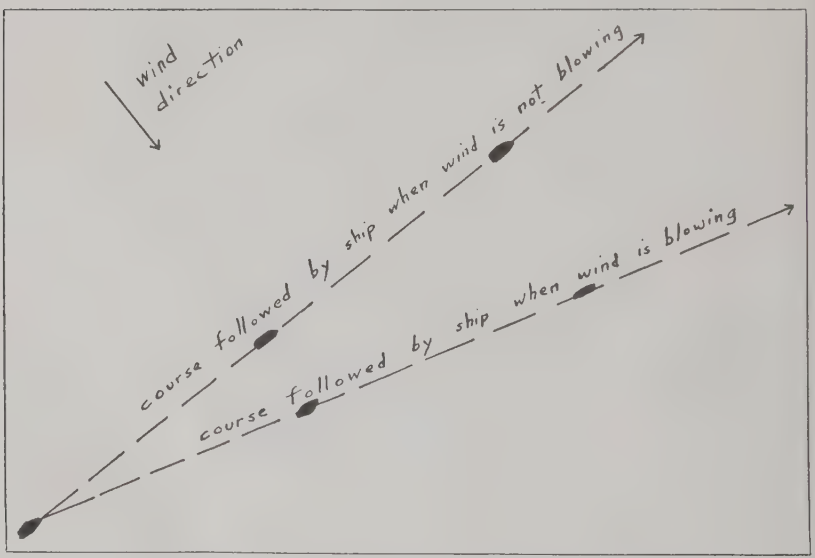
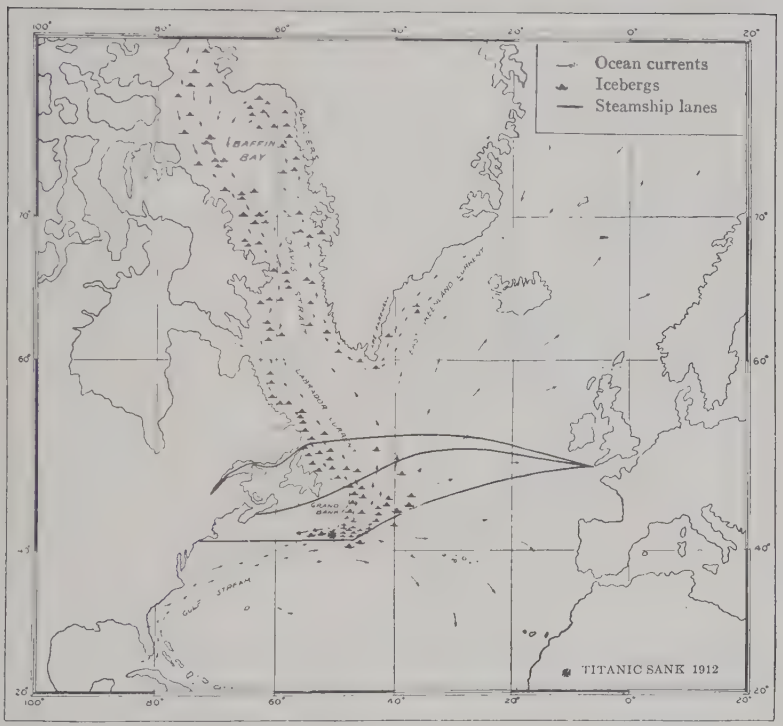


FIG. 345.—Diagram illustrating the effect of wind on the course followed by a ship kept constantly headed in the same compass direction,



Courtesy of Hydrographic Office, United States Navy

FIG. 346.—General drift of icebergs which may menace North Atlantic steamship tracks in the spring and early summer.

After the Deutsche Seewarte

FIG. 347.—Sailing-vessel routes recommended for midsummer in the Northern Hemisphere and midwinter in the Southern Hemisphere.

Stippled areas have steady easterly winds, the Northeast Trades in the Northern Hemisphere and the Southeast Trades in the Southern Hemisphere. On the borders of both Trade Wind zones lie belts where calms prevail much of the time. Over the Arabian Sea and the Bay of Bengal the Southwest Monsoons are blowing at this season. In the middle latitudes the winds are variable: in the Southern Hemisphere, "The Roaring Forties," strong westerly winds, predominate; in the Northern Hemisphere westerly winds are stronger and more common than easterly winds. These wind belts shift north and south with the seasons (i.e., with the sun) but the winds do not alter their general direction except over the Arabian Sea and the Bay of Bengal, where Northeast Monsoons blow during the northern winter.

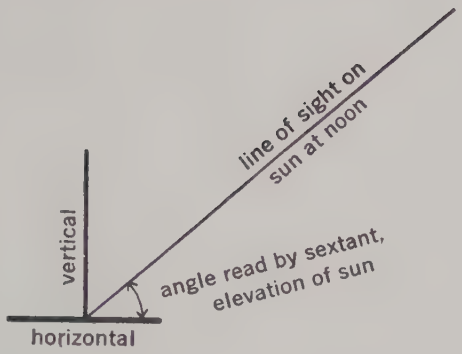


FIG. 348.—Diagram illustrating the use of the sextant

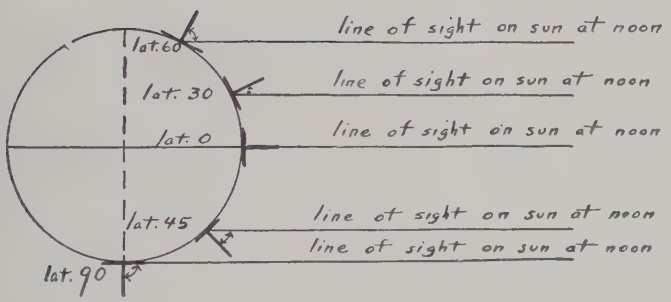

lat. 60
lat. 30
lat. 0
lat. 45
lat. 90
line of sight on sun at noon
line of sight on sun at noon
line of sight on sun at noon
line of sight on sun at noon
line of sight on sun at noon

FIG. 349.—Diagram illustrating the application of sextant readings to the determination of latitude. The angle between the vertical and the line of sight on the sun is the complement of the sextant reading.

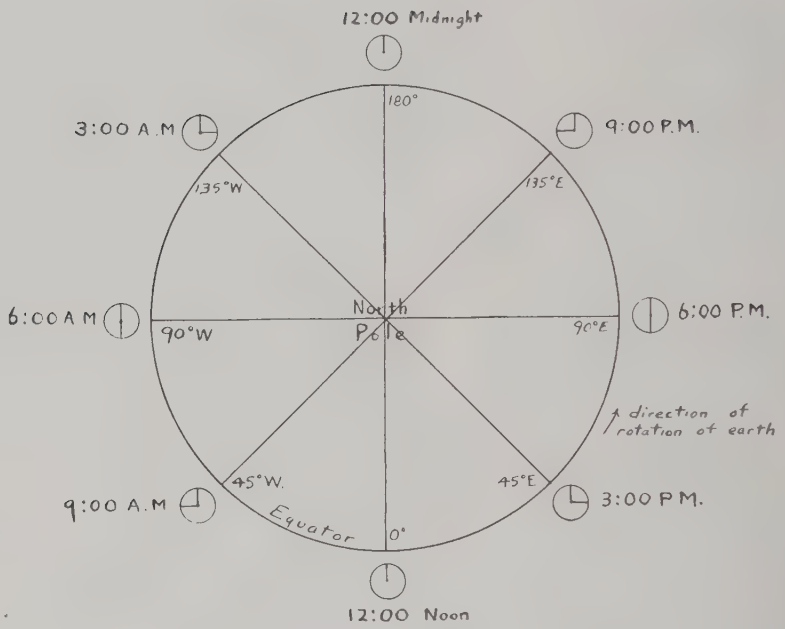


FIG. 350.—Diagram showing time on selected meridians when it is noon at Greenwich, England, longitude 0°.

After Hydrographic Office, United States Navy

FIG. 351.—Standard Time Zones and International Date Line

To provide for keeping standard time at sea, the surface of the globe is divided into 24 zones, each bounded by meridians 15 degrees (1 hour of time) apart in longitude.

The initial zone is the one which has the meridian of Greenwich (shown by a broken line) running through the middle of it, and the meridians $7\frac{1}{2}^{\circ}$ east of Greenwich and $7\frac{1}{2}^{\circ}$ west of Greenwich marking its eastern and western limits. This is called the zero zone because the difference between the standard time of this zone and Greenwich mean time is zero. The zones lying in east longitude are numbered in sequence from 1 to 12, and are called minus zones, because, in each of them, the zone number must be subtracted from the standard time in order to obtain Greenwich mean time. The zones lying in west longitude are likewise numbered in sequence from 1 to 12, and are called plus zones, because, in each of these zones, the zone number must be added to the standard time in order to obtain Greenwich mean time. The 12th zone is divided medially by the 180th meridian (the line separating the meridians of east longitude from the meridians of west longitude), and the terms minus and plus are used in the halves of this zone which lie in east longitude and west longitude respectively.

In the vicinity of the land, the boundaries between zones are modified so as to be in accord with the boundaries of the countries or regions using corresponding times. In actual practice the boundaries of time zones on land are determined by the frontiers of countries or by railroad division points, and agree in a general way with those at sea.

The countries where legal time is based on the hourly zone system are shown (*a*) in black if the zone numbers are even, and (*b*) in horizontal lines if the numbers are odd. Countries where the legal time differs half an hour from the neighboring zones are shown in vertical lines. Countries that have not yet adopted the zone system are shown in stipple. Because of the small scale of this map no attempt is made to show the time of the many small oceanic islands.

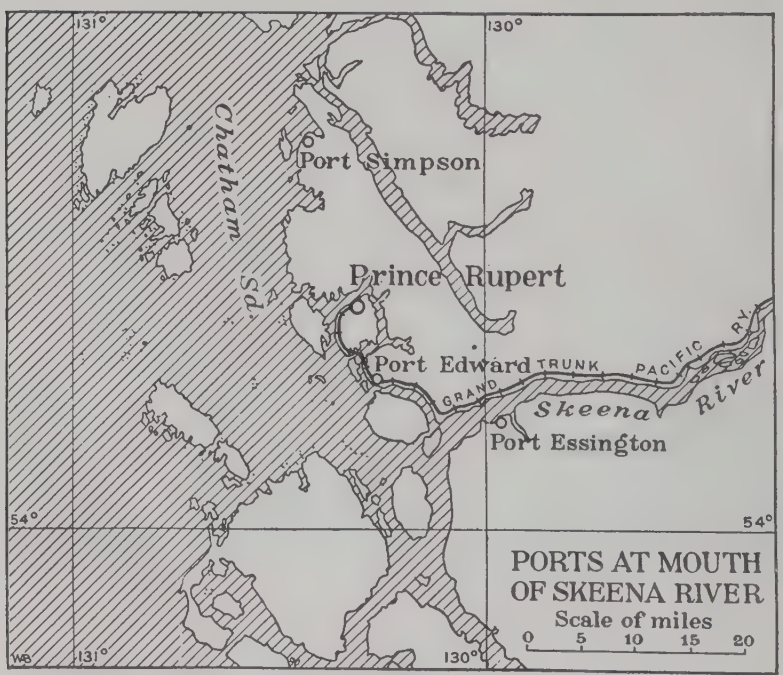
Date Line. On board vessels at sea the date is changed upon crossing the 180th meridian. On either side of the Date Line (shown by a broken line) the day of the week and the date of the month differ by one day, the date on the Asiatic side being later than that on the American.

Courtesy of United States Army Air Service

FIG. 353.—Boston Harbor from the air

Courtesy of E. B. Oppi

FIG. 354.—Fiord harbor of Svolvaer, Lofoten Islands, Norway



Courtesy of American Geographical Society—Tower

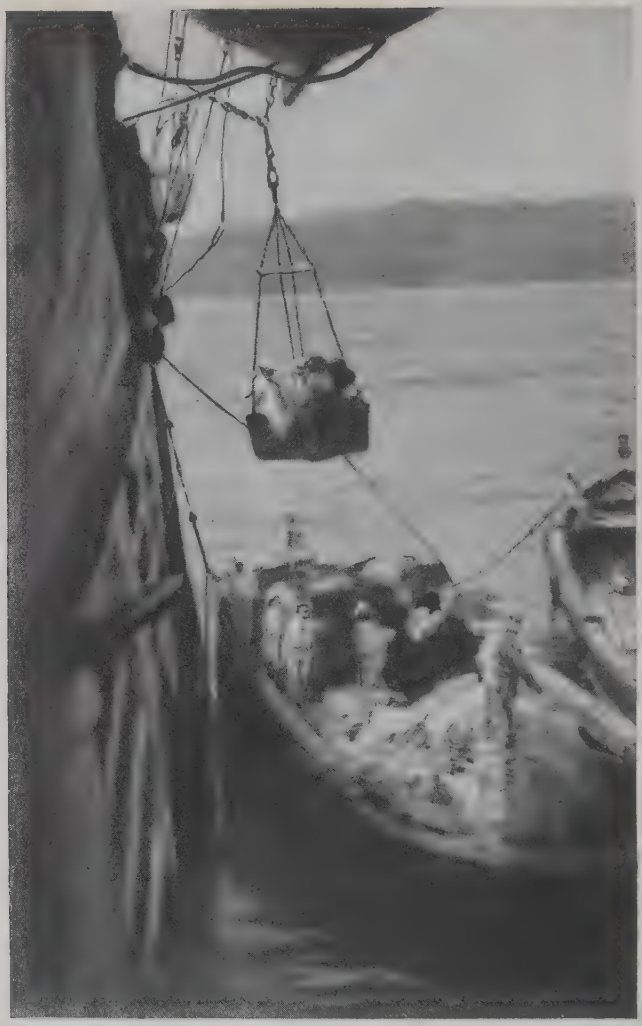
FIG. 355.—Ports along the fiord coast of British Columbia, near the mouth of the Skeena River. (From the *Geographical Review*, published by the American Geographical Society of New York.)

W. D. J.

FIG. 356.—Wheat awaiting shipment on the wharves at Karachi, India

W. D. J.

FIG. 357.—Ships at anchor off the harborless coast at Iquique, Chile



Courtesy of H. S. Kemp

FIG. 358—Unloading passengers from steamer to lighter off the harborless eastern coast of Costa Rica.

W. D. J.

FIG. 359.—The harborless coast line at Madras, India

W. D. J.

FIG. 360.—A part of the artificial harbor at Madras, India

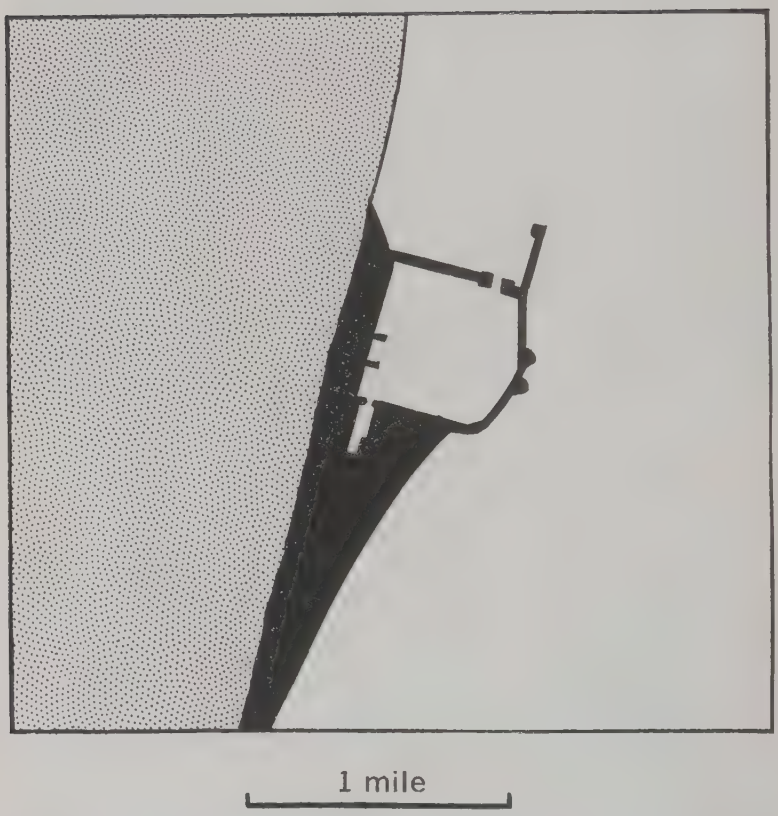


Fig. 361.—Madras Harbor, India. Harbor works and made land in solid black.

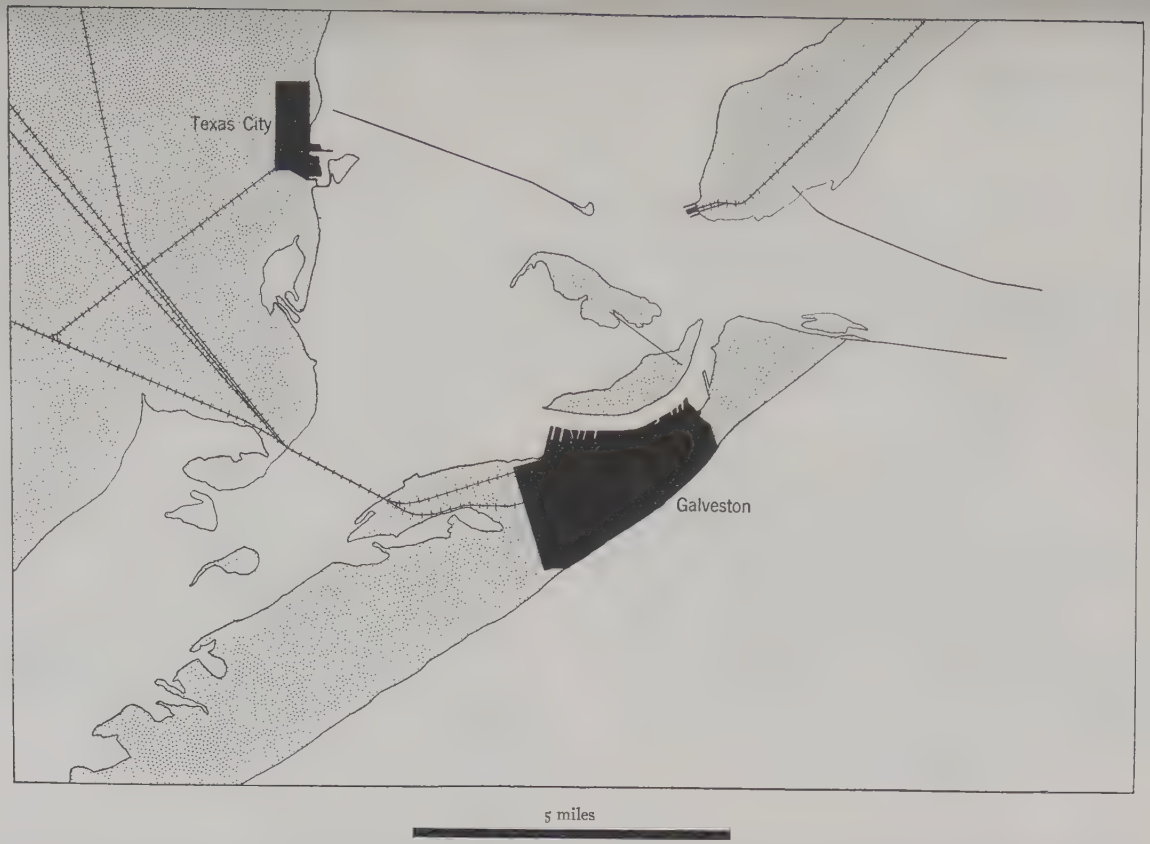


FIG. 362.—The lagoon harbor of Galveston, Texas. Note the jetties, concentrating outflowing tidal current, the railroad connecting the city with the mainland by a causeway across the lagoon, and the harbor proper at the northern edge of the city.

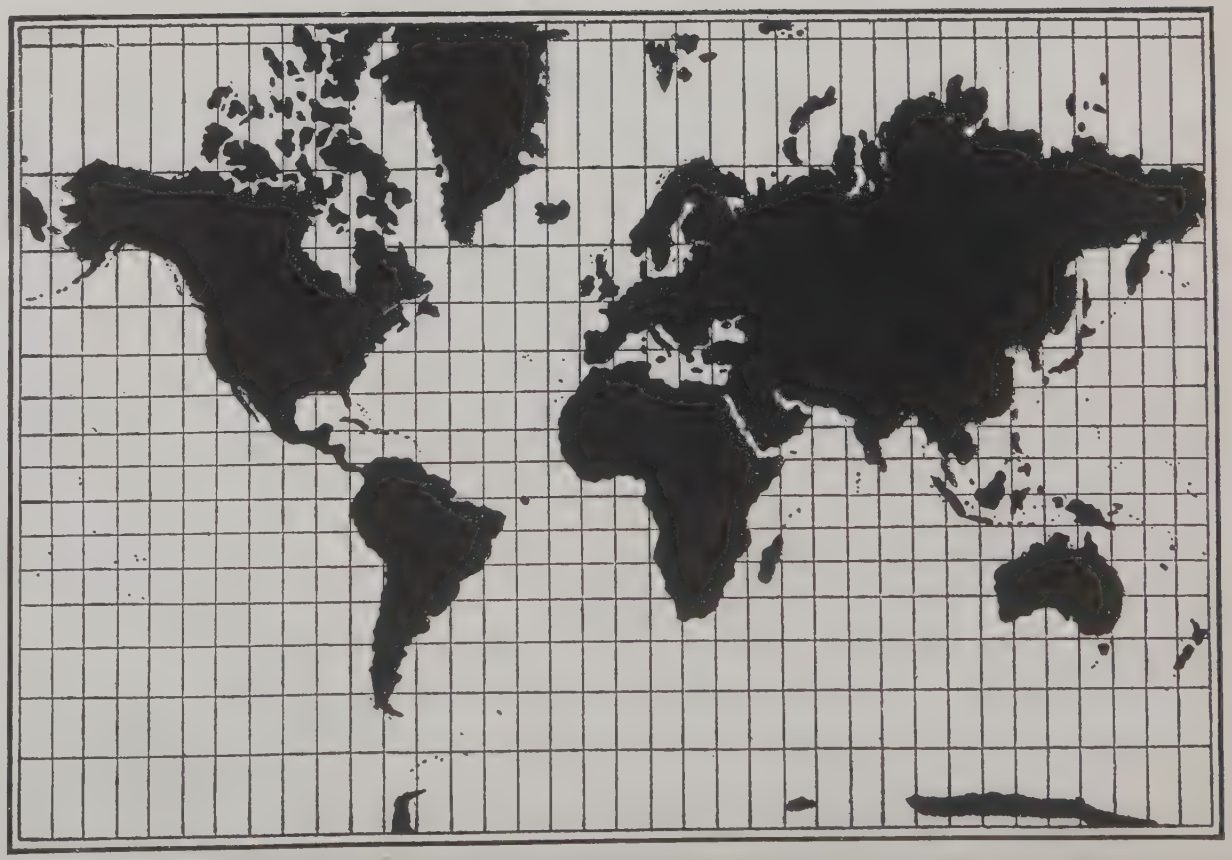


FIG. 363.—The world on Mercator's Projection

Courtesy of J. Paul Goode

FIG. 364.—The world on Goode's Homolosine Projection

FIG. 365.—The world on Mollweide's Homolographic Projection

Ewing Galloway

FIG. 366.—Eastern Kentucky hillside coal mine. Two essentially horizontal strata of coal which outcrop on the slope are worked by drifts driven into the hill. The coal, brought out from these drifts in small cars, is conveyed down to the tipple in the valley bottom, where it is loaded on to railroad cars for shipment.

LIBRARY OF DAVIDSON COLLEGE

A fine of **five cents** a day on ordinary books, and of **five cents an hour on reserved books,** is due after date stamped.

Special books are subject to special regulations at the discretion of the library staff.

Jones 330.9
AUTHOR J79i
An introduction to v. 1
TITLE economic geography
BORROWER'S NAME

Jones 330.9
J79i
An introduction to v. 1
economic geography